Plashetts and Kielder. CLOUGH

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF

PLASHETTS AND KIELDER

(EXPLANATION OF QUARTER-SHEET 108 S.W., NEW SERIES, SHEET 7.)

BY

C. T. CLOUGH, M.A., F.G.S.

(NOTES ON THE CUMBERLAND PORTION BY HUGH MILLER, A.R.S.M., F.G.S.)

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PREFACE.

The area included in the Map described in the present Explanation lies along the north-western borders of Northumberland and Cumberland, and includes the upper waters of the River North Tyne and its tributaries. It was surveyed by Mr. C. T. Clough (with the exception of the Cumberland portion, about half a square mile in extent, which is the work of Mr. Hugh Miller,) under the supervision of Mr. H. H. Howell.

Almost the whole of the ground lies upon the lower members of the Carboniferous system. There can be little doubt that the Lewisburn and other coals of this region are the stratigraphical equivalents of the "Scremerston beds" in the Carboniferous Limestone Series of the north-eastern portion of Northumberland. The determination of this point is the chief feature in the investigation of the district by the Geological Survey.

The six-inch sheets of the Ordnance County Maps included in the area of Quarter-Sheet 108 S.W. one-inch, are, Cumberland Sheet 2; Northumberland, Sheets 33, 40, 48, 49, 57, 58, and the western borders of Sheets 34 and 41. The ground was surveyed geologically on the six-inch scale, and MS. copies of these sheets are kept in this office for consultation by the public.

The fossils mentioned in this Memoir have been mainly determined by Messrs. Sharman and E. T. Newton, who have also revised all the fossil-lists here given.

ARCH. GEIKIE,
Director-General.

Geological Survey Office,
28, Jermyn Street, London,
20th December 1888.

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THE GEOLOGY OF

PLASHETTS AND KIELDER.

CHAPTER I. INTRODUCTION.

Physical Geography.

The area of the quarter sheet is about 66½ square miles. The boundaries on the south and east sides are lines drawn nearly due east and west and north and south respectively: on the north and west sides the boundary is the Scottish Border. This Border for the distance between the north end of the map and Thorlieshope Pike—the projection three-quarters of a mile W. of the head of the Tyne—keeps to the watershed between the North Tyne tributaries on the English side and those of the Teviot and Liddel on the Scottish side, with the exception of about two square miles between Peel Fell and Knox Knowe, which, though within the North Tyne area, is included in Scotland. From Thorlieshope Pike to a point half a mile south of where the Oakenshaw Burn Road crosses it the border runs entirely within the North Tyne area, and generally at a distance from the watershed of about three-quarters of a mile. After this it crosses over the watershed on to the Liddel side and runs down Kershope Burn, a tributary of the Liddel. The Liddel flows into the Solway and so into the Irish Sea.

Thus with the exception of about one square mile in the south-west corner the whole sheet belongs to the North Tyne drainage area. But there are three or four square miles in the north-east corner which first drain into the Rede, and this has to travel a long way before it joins the North Tyne.

The North Tyne traverses the sheet from north-west to south-east. The chief streams that come into it from the east are the Kielder Burn, Plashetts Burn and Belling Burn, and from the west Bell's Burn and Lewis Burn. The Kielder Burn is itself much longer and larger than the Tyne above their point of junction, but the valley of the latter stream keeps on in the same line as that of the united streams below their junction, and this is doubtless the reason it still claims the title of North Tyne. The pass too at the head of it crossing over into the Liddel is very marked, so that one passes over the watershed of the country here quite imperceptibly. It is occupied by a spread of alluvium and peat moss, and the lowest point is only a little over 700 feet above Ordnance Datum.

The entire area is wild and somewhat hilly, and contains very little enclosed ground. Peel Fell, 1,975 feet, is the highest hill,

Carter Fell, 1,899 feet, comes next, and in the north half of the sheet there are various other heights only a little lower than these. In the south half both the hill tops and the general elevation are somewhat lower.

Geological Literature.

It is believed that the following list includes most of the papers, &c. of importance that refer to the geology of the area :—

1816. N. T. WINCH. Geology of Northumberland and Durham. *Trans. Geol. Soc.*, vol. iv. p. 1.

1824. W. SMITH. Geological Map of Northumberland (in part by PROF. J. PHILLIPS).

1851. PROF. A. SEDGWICK. On the Geological Structure and Relations of the frontier chain of Scotland, with a list of Organic Remains by PROF. MCCOY. *Brit. Ass. Rep.* In 1850 section p. 103.

1857. REVEREND JOHN HODGSON. Memoir of Reverend John Hodgson by Reverend James Raine. Contains (p. 139) Minute of a journey to Mounces in 1814, and other casual references to geology.

1861–2. NICHOLAS WOOD. On the Upper and Lower Beds of Coal in the Counties of Northumberland and Durham. *Trans. N. of England Inst. Eng.*, p. 99, vol. xi. Discussion, pp. 194–196.

1875. G. A. LEBOUR. The larger divisions of the Carb. system in Northumberland. *Trans. N. of England Inst. Eng.*, vol. xxi. p. 225.

1877. G. A LEBOUR. On the terms Bernician and Tuedian. *Geol. Mag.* Decad. ii., vol. iv. p. 19.

1878. G. A. LEBOUR. Outlines of the Geology of Northumberland. 8vo. Newcastle. Refers especially to this area on pp. 38, 39, 42, 50, 51. (2nd Ed. in 1886.)

1878. G. A. LEBOUR. Geological Map of Northumberland.

Table of Formations and Brief Description of some of them.

Recent	Alluvium and Terraces.	
	Basin-Peat, Hill-Peat.	
	High River Gravels.	
Glacial.	Boulder Clay. Sands and Gravels.	
Lower Carboniferous	Carbonaceous Series and Fell Sandstones.	
	Cementstone Series.	
	Lower Freestones.	
Upper Silurian.	Wenlock shales and greywackés.	
Contemporaneous Igneous Rocks. Carboniferous.		Carter Fell Ash (Tuff).
		Carter Fell Basalt.
Intrusive Igneous Rocks.	Basalt dykes.	

The lowest group of the carboniferous is, as its name implies, essentially a sandstone group. The middle one is more a shaley group with many thin bands of impure limestone (cementstone). The highest one, Carbonaceous Series and Fell Sandstones, is in its lower part essentially a sandstone group again, but the upper

part may contain in places a very large proportion of shale, limestone, and thin coals.

It is somewhat doubtful whether the Carter Fell basalt be contemporaneous or intrusive. If it be taken as contemporaneous there are only the basaltic dykes left to represent the intrusive rocks.

Silurian Rocks.

These rocks are not actually exposed in this sheet, but there is little doubt that a very small area of them comes into the north-east corner. In the bed of a small sike, about 18 yards east of the south end of the area as mapped, Silurian shales occur and are stained purple, as the Silurians strata in the adjoining map to the east (108 S.E.) are when in the neighbourhood of unconformable Carboniferous beds.

The series in Sheet 108 S.E. consists chiefly of shales and greywackés, probably of Wenlock age. They have been traced south-west into Kirkcudbright, and abundant fossil evidence is there obtained.

CHAPTER II. CARBONIFEROUS ROCKS.

These may be conveniently divided into the following groups, in descending order:—

1. { Carbonaceous Beds.
   { Fell Sandstones.
2. Cementstone Group.
3. Lower Freestones.

The upper group is made by Prof. G. A. Lebour * the base of a Bernician Series, a series which extends up to the base of the Millstone Grit of Northumberland. The beds from the Fell Sandstones to the base were classed by the late George Tate of Alnwick as Tuedian, in at least the northern part of the county. It is probable that they all represent lower portions of the Carboniferous Limestone Series of the country further south.

Lower Freestones.—These consist of rough-surfaced flaggy sandstones with numerous small ochre spots and variegated lilac red and grey clays, which here and there contain bands of ochreous slightly calcareous concretions. The sandstones too are occasionally a red colour. Near the head of the sike by the bend of the Redesdale main road they contain chert, but whether in nodules or bands is not clear. There are no very good sections within this Map: perhaps the best is the one in the small east to west sike that occurs within three-quarters of a mile of the extreme north end of the Map.

The thickness in and near the Map may be taken perhaps at about 200 feet.

Cementstone Group.—This consists of a series of shales and thin clayey limestone courses—cementstones—with subordinate sandstones. The shales have usually a greenish tint, and the limestones weather yellow on the outside and contain but few organic remains. Individual courses often vary very rapidly in thickness, a 3 or 4 ft. series thinning out into 1 ft., or a thinner set into scattered nodules or entirely dying out. This is seen very well in the burn along the Border west of the Trouting. Occasionally however the limestones attain a considerable thickness, 12 or 16 ft., and contain also remains of crinoids, *e.g.*, on the fellside east of the Three Pikes.

Where best developed there is a conspicuous absence of anything that could be called a coal seam, though thin carbonaceous streaks are sometimes seen, *e.g.*, in the east-west cleugh, a little over half a mile east of Kielder Head.

Many of the sandstones are very calcareous and occasionally give rise to swallow holes. Each little quartz grain exposed on

* Outlines of the Geology of Northumberland, p. 42, 1878-9; p. 58 of 2nd Ed., 1886.

their weathered faces sticks out prominently, and frequently the successive lines of them strike against one another, and bring out the false-bedded character very distinctly. Occasionally the more calcareous portions seem collected together in more or less rounded lumps. A quarter of a mile north of the "G" of "Gowanburn Moor" a limestone has been extensively quarried and burnt, but the quarry is now abandoned; the thickness is said to have been 13 ft. Some bands in it are a good blue colour and may be of coral origin, but others should rather be called calcareous sandstone than limestone and contain coal-pebbles and plants.

The highest bed in the series often consists of a rather thick limestone or calcareous sandstone. At the head of Bateinghope Burn it is a sound compact cream-coloured limestone, and has been worked in a level for lime burning. In the burn west of the Trouting there is also a conglomerate of limestone fragments on this horizon. The best sections occur in Deadwater Burn, White Kielder Burn, and the cleughs next east of Kielder Head.

The thickness of the series on the Carter Fell is perhaps about 400 ft. In Tynedale there is evidence for up to 600 ft. at least: the base is never reached.

Carbonaceous Series and Fell Sandstones.—This double group is much the largest of the three divisions into which the Carboniferous beds are divided in the map, and it includes in some places beds of such shaley character that the term Fell Sandstones seems inappropriate. The term was applied originally to the thick massive freestones of Larriston and Peel Fell. Coming on above these, or perhaps in them, in some cases, there is an enormous development of shales, thin coals, limestone courses, &c., apparently the representatives of what George Tate in the north of the county called the Carbonaceous Beds of the Carboniferous Limetone Series. These were not separated in the course of the field survey, and, in all probability, it would be found impossible to separate them by any single line, if the groups were to retain their distinctive characters over large areas. Every here and there we should doubtless have to pass from one boundary line, across a considerable thickness of beds, to take up another on a different horizon. Moreover, intermixed with the shaley beds there are occasionally freestones so massive and thick, that the character of the ground is quite comparable to that formed by the sandstones of Larriston and Peel Fell. For the further discussion of the relations between the Carbonaceous Beds and the Fell Sandstones, see p. 36.

In the south-east portion of the sheet there is an especially great development of these shaley carbonaceous beds. Capital sections of them are seen in the Lewis Burn valley, and they may hence be well designated the Lewisburn Beds.

The typical Fell Sandstones of Peel Fell, &c., consist of a series of massive false-bedded freestones with subordinate shales or clays and rare limestones and coals. Usually the freestones are close together and thick so that they form rough, heather-clad fells with scar after scar. Good sections occur in the burn

running north-east from the top of Peel Fell, the burn south-west of the Trouting, the Carry Burn, the Cross Cleugh (Bateinghope) and many other places. Much the largest proportion of the constituent grains in the sandstones consist of quartz, and are generally only of small size and loosely cemented together. The larger ones perhaps average $\frac{1}{40}$ in. in diameter, but exceptional pebbles up to 1 in. in length are found in certain places, *e.g.*, a little over 1 mile north of Kielder Head. The scars often weather in extremely massive blocks which show falsebedding clearly. The difference in hardness of the different bands causes a difference in the mode of weathering, and we may thus get blocks deeply undercut or marked by a series of constrictions where the softer bands occur, *e.g.*, in the Dove Stones rather over 1 mile east of Kielder Head. The "Bore" (wrongly Boar in the map) Stone on Deadwater Moor has been pierced right through by the weathering away of some softer parts: the average length of the bore is 9 ft., the height 4 ft., and the width 5 ft.: the stone stands out almost isolated by denudation from the scar to which it belongs. The outermost of the "Leaping Stones," about 1 mile east of the top of Mid Fell is quite thus isolated, but the chasm across which the leap has to be made is only 3 or 4 ft. wide.

Occasionally the laminæ in the blocks are sharply curved and twisted, giving an appearance of severe contortion, though the base-line of the bed may continue running evenly; but this may be due to concretionary action. It is seen particularly clearly in a strong scar about a quarter of a mile west of the top of Mid Fell.

Other of the beds weather in more low-lying somewhat pillow shaped masses with soft rounded outlines, *e.g.*, at the Gray Mare's Knowe, a mile and a half north of Kielder Head.

A strong sandstone scar near the top of Deadwater Fell contains numerous dark brown sharply defined projecting thin bands which vary in thickness from 2 or 3 in. downwards. On examining a hand specimen they are at once felt to be heavier than the unstained sandstone, and fresh fractures show a difference in first the deeper tint and secondly the multitude of small glistening specks they display. The brown tint is due to an earthy brown or yellow substance, in all probability the hydrous peroxide of iron, which fills the spaces between the quartz grains, which are often left unfilled in the normal sandstone. The glistening specks are fresh fractured quartz grains, the rock being so firmly compacted by the brown substance that it has in many cases broken across these grains, a thing which never seems to happen in the normal sandstone. The quartz grains themselves are perfectly free from staining. There is never any fissure- or vein-mineral on the sides of the bands, and they never throw the bedding planes they cross. The stronger bedding planes are readily recognisable in them, weathering in relief.

They often present the most complicated appearance; rudely vertical lines changing into horizontal and back again quite

capriciously. Some are visible for 12 yds. or more, and may continue very much further; indeed it is possible that they are all connected in some way or other. Sharp curves in them are very numerous, and, when we get the appearance of many rudely parallel lines, examination often shows that they are each but repeated sections of a band that has a habit of sharply bending.

Similar stained bands may be seen in various places between the head of Archer Cleugh and the top of Deadwater Fell, a quarter of a mile north-west of the north and south sike on Ravenshill Moor and other places.

Sometimes the different parts of a sandstone that has up to a certain point formed only one scar commence to form each a separate feature for itself. This is the case a little east of the track leading north from Kielder Head, about three-quarters of a mile above the house. The softer portions of the sandstone seem of themselves often sufficient to cause the separation in the features without the intervention of any shale.

At several points between 100 yds. south-east of Mid Fell top and a little over a quarter of a mile slightly east of south thereof, there are large swallow holes going through massive but not evidently calcareous sandstones.

The base of the series does not keep to one particular bed, but we are obliged every here and there to cross to a higher or a lower one than that we had hitherto taken, if this line is to retain its character as a division between the more sandy and the more shaley portions of the section. Thus coming south along the base line south-east of the "Grun" we pass on to a lower bed, and coming south along the base near the Bore Stone, we cross over several beds of a considerable thickness in all. Still the classification as a whole is a very natural one.

The bed taken as the base in the cleugh that comes into Scalp Burn from the west, by the "p" of "Scalp Burn," is a massive calcareous sandstone with conglomerate bands containing quartz pebbles and quartz mixed with tourmaline.

A little way above the base we generally come to a series of peculiar variegated purple chocolate and grey clays, interbedded with the freestones, and sometimes associated with thin green-hearted sandstone courses and bands of rough-surfaced limestone lumps, the outsides of which are the same colour as the clays. The clays have been washed and carefully examined for minute organisms, but hitherto without success. It has been suggested that they are fine volcanic sediment. They are seen on the east side of Carter Fell between the basalt and the coal, near the foot of Carry Burn, near the head of Scalp Burn, the landslips on the east side of White Kielder, and Catcleugh Burn (Kielder Station), &c.

An associated limestone is seen at the head of a slip in the White Kielder, two-thirds of a mile north-north-east of the Woody Crags, and on Deadwater Moor a quarter of a mile south-south-west of the Bore Stone.

Above these variegated clays comes ordinarily a Carbonaceous Division with many thin coal seams, more shale than usual, and occasionally, *e.g.*, in the Rigend Burn east of Ewe Hill, a good many thin impure limestone bands, not much different from those of the Cementstone series, excepting that distinctly marine fossils are abundant. The shales have also sometimes a greenish tint as in the Cementstone series, but more usually they are dark grey and carbonaceous.

From the base of the Fell Sandstones in Bateinghope Burn up to the Carter Fell coal the total thickness is probably a little over 600 ft., mostly all of sandstone. On the Peel Fell escarpment there must be at least an equal thickness of very similar beds without getting up to the coal.

The Carter coal where worked is said to have been about 13 ins. thick. A little way above it there are two good limestones both forming swallow holes and containing corals, crinoids, &c. The lower one is seen very well in Carry Burn about one third of a mile below its head. There are some large blocks too in the Cross Cleugh (Bateinghope), about 180 yds. below its head, which may belong to it and be in place. The upper limestone was formerly extensively worked in two large quarries near the head of Bateinghope Burn; it appears made up in great part of rolled pebbles of limestone, containing corals, Productus, &c., with the interspaces filled with a sandy green shale. The thickness at present exposed is about 10 ft., without getting to the bottom; immediately on the top comes 6 ft. of sandstone. It is worth while mentioning here that throughout the Map generally there is no universal rule determining whether sandstone or shale shall occur at the bottom or top of a limestone, although in the district further south and in the Carboniferous Limestone Series of Durham and North Yorkshire, it is almost invariably the case that sandstone occurs below limestone and shale above it.

The Lewisburn or Carbonaceous beds in the south-east part of the sheet have been already briefly alluded to (p. 5). They will be shown (p. 36) clearly to come above the mass of the sandstones of Peel and Larriston Fells. They resemble the Cementstones proper in some respects, but differ therefrom in, first, the great number of coal seams they contain, and, secondly, the greater frequency of marine fossils, *Rhynchonella*, *Polyzoa*, &c. in the limestone bands.* These limestones are generally very impure and most of them should perhaps rather be called calcareous flagstones: they are generally very hard, of a dark grey colour internally, and contain numerous plant remains in conjunction with the fossils already mentioned. Some of the bands are however purer and thicker, and there is one which comes twice into Lewis Burn, at points about 100 yds. and one quarter of a mile below the Low Long House, which has been quarried and burnt for lime on the fell-side about half a mile east-south-east of the Forks. Its thickness

* Detailed sections of the Lewisburn beds will be found in the Appendix, pp. 56–59.

is about 11 ft., including in places a 3 ft. shale parting, and it is characterized by the presence of a large *Productus*. The limestone that crosses the Tyne east of Wellhaugh Moor is of much the same character and is probably the same. Possibly too the limestone at Belling Burn foot is the same.

The sandstones are sometimes very massive but are given to sudden variations in thickness and character. This is seen very well on comparing the different developments of individual beds in the adjoining reaches of the burn below Low Long House. Plant remains and thin coal streaks are abundant. Some of the finer bedded sandstones show an excessively fine even succession of more sandy and more shaley laminæ, *e.g.*, in the burn about a quarter of a mile above the Forks bridge.

The shales frequently contain thin courses, averaging perhaps only 1 or 2 in. in thickness, of clay ironstone, or detached nodules of the same. A number of grey marly nodules full of Mytilus-like shells, univalves, and small reed-like stems occur in the shale in the burn about a quarter of a mile above Low Long House.

In many places coals occur once in every 30 or 40 ft. of the section, but they are generally only thin—often about 8 in. There are all gradations from hard blocky coals, locally called "splints," to carbonaceous shale, and a comparison of sections but little distant from one another often compels one to assume a very rapid variation in their character, or even a dying out of old seams and coming in of fresh ones on different horizons.

The supposed Plashetts seam is seen in two places in the Lewisburn valley: first in an east to west sike at a point 400 yds. south-east of Low Long House, and again in a deep drain rather less than half a mile east-south-east of the house. In the former locality a level was started, and the seam is said to have consisted of two 11-in. bands separated by 10 in. of sagger (fireclay); but it was so burnt up by the basaltic dyke that the undertaking was speedily abandoned. In the drain the thickness as reported by the late Mr. T. J. Taylor is 4 ft. 11 in. Where worked on the north-east side of the Tyne the thickness averages 3 ft. 9 in. It is often characterized by the presence of a 1 or 2 in. shale parting about 15 in. from the bottom, and by a roof of a shelly calcareous band about 8 in. thick which contains many minute Entomostraca. In the adjoining Map 108 S.E. there is an Entomostracan band about 5 ft. above the coal. In the working colliery near Bellingburn Head the greatest normal thickness is said to be 5 ft. 2 in. and the least 2 ft., but it is reduced now and then even to 14 in., either by being locally nipped by a roll down of the roof, the base remaining level all the time, or by the incoming of a thick wedge of shale near the middle of the seam. Above the main coal is another the thickness of which varies from 6 in. to as much as 18 in., and its height above the main from 5 ft. to as much as 20 ft.

As stated in describing the Dry BurnFault, &c., p. 46, the coal of the old level near the "n" of Dry Burn is probably the Plashetts seam on the upthrow side of the faults. The supposed east to

west Wainhope Moor Fault should a little north of the level again throw it, and many of the miners look upon the seam running under Monkside as it on the upthrow side of the fault. This correlation is doubtful, but if it be accepted, then we must suppose that the beds seen below the Plashetts seam in Lewis Burn, &c. represent the shaley beds that come below the seam on Monkside. As far as we can judge the thickness of such beds is very much less in the latter locality than the former, but that of course is no insuperable objection.

The Piper's Cross* Limestone forms a conspicuous green swallow hole forming band by the site of the old cross on the drove road between Wainhope and Bellingburn Head. It is good blue limestone with many corals and crinoids, and has been worked in many small old quarries. The thickness is probably not more than 15 ft. The distance in the section above the Plashetts coal is perhaps about 460 ft., mostly of freestone. The overlying bed is a shale with ironstone nodules; the underlying bed, one-third of a mile north-east of Bellingburn Head, is a 2 or 3 ft. sandstone with many specimens of Spirifer, Productus, &c.

Good sections of beds which probably belong to the lower part of the Lewisburn series occur in Kershope Burn, the burn along which the Scottish Border runs west of Caplestone Fell. The beds consist of sandstones, grey shales and marls, occasional thin coals and impure limestones bands. The limestones and calcareous grits are not free from carbonaceous matter, and there is the not unusual tendency for the coals to underlie the limestones, an arrangement which perhaps points to jerks of subsidence during formation.

In a burn that comes into Kershope Burn from the east near Kershope Head, about 200 yds. outside the margin of the Map within (106 N.W.), there is a section somewhat as below beginning with the top—

	Ft.	In.
Sandstone, fine grained.		
Shale, obscure.		
Flaggy limestone with cherty courses weathering with a fine lamination. *Crista Galli* and fragments of plants: and encrinites near the top - - -	8	0
Shale with plants - - - - 3 ft. to	4	0
Chert, grey and glancing in its upper part: shells replaced by chalcedony - - - -	2	0
Shale, obscure - - - - - -	6	0
Sandstone.		

These chert beds resemble the beds not far above the horizon of the contemporaneous Basalt of Kershope Foot, &c. (Sheet 11, Scotland).

* The cross is (1882) no longer standing, but two fallen freestones remain to mark the site, which is about 50 yards east of the point of the dip arrow marked in the map. The other stones are said to have been removed some years back for wire fence foundation stones.

CHAPTER III. CARBONIFEROUS ROCKS—*continued.*

PALÆONTOLOGY.

The fossils in the following lists, excepting those of 28*a*, were collected by Mr. John Rhodes, assisted in some cases by Mr. Arthur Maconochie, of the Geological Survey of Scotland. The determinations are by Messrs. G. Sharman and E. T. Newton, except for Nos. 18*a*, 19*a*, 28*a*, and 31*a*., the authorities for which are specially mentioned.

Cementstones.—We give first the list of localities from within the presumed Cementstone area which have yielded fossils to the collectors of the Survey, and then the combined list of fossils obtained from these localities. To show the different fossils collected from the different localities each locality is distinguished by a number—1, 2, &c., and to each fossil are attached the numbers denoting the localities in which it has been found.

We should observe that the exact position of locality 9 is not remembered with certainty.

Cementstone Localities.

1. Burn about ¾ mile S.E. of Kielder Head: impure cement limestone.
2. Burn about ⅝ mile east of Kielder Head: dark sandy shale between sandstone.
3. Archer Cleugh 1½ mile N.N.E. of Kielder Castle: dark sandy shale.
4. Archer Cleugh, two miles north of Kielder Castle: dark sandy shale between sandstone.
5. Deadwater Burn, one mile and a half north-east of Deadwater.
6. ,, ,, one mile and three-quarters north-east of Deadwater.
7. White Kielder, one mile and a half north-east of Kielder Head: impure limestone in bed of burn.
8. Near head of White Kielder: limestone.
9. Bateinghope Burn, near junction with Cross Cleugh?: grey sandy shales.
10. Bateinghope Burn, near by the "i" of "Bateinghope": grey sandy shales.
11. Black Needle Burn, 2¾ miles N.N.W. of Kielder Head.
12. Stream, three-eighths of a mile east of Kielder Castle: dark sandy shale.
13. Catcleugh Burn, about ⅜ mile S S.W. of Kielder Station: thin bed of limestone over sandstone.

Cementstone Fossils.

		No. of Locality in foregoing List.
Plantæ	Calymmatotheca bifida, *L. & H.*	10
	Lepidodendron (Knorria condition)	3
	Palæophycus, sp.	2
	Pinnularia-like fossil	2
	Rhabdocarpus, sp.	6
	Sphenopteris, sp.	10
	,, ,, allied to S. elegans	2
Actinozoa	Chætetes	7
Echinodermata	Crinoid ossicles	31

		No. of Locality in foregoing List.
Annelida	Serpula subannulata, *Port.*	1, 11
	Spirorbis helicteres, *Salter*	8
Crustacea	Cytherella, sp.	12
	Crustacean fragment	5
	Leperditia, Okeni. *Munst.*	10
	,, sp.	13
Brachiopoda	Discina nitida, *Phil.*	12
	Lingula mytiloides, *Sby.*	4
	Rhynchonella pleurodon, *Phil.*	12
	Spirifera distans., *Sby.*	13
	Spiriferina laminosa, *McCoy*	13
Lamellibranchiata	Aviculopecten knockonniensis, *McCoy*	12
	Axinus carbonarius, *Port.*	12
	Modiola, sp.	12
	Myalina, sp.	10
	Sanguinolites, sp.	12
Gasteropoda	Loxonema, sp.	8
	Macrocheilus, sp.	8
	Murchisonia quadricarinata, *McCoy*	8
	,, sp.	11
Pisces	Archichthys Portlocki, *Ag.*	9
	Ctenoptychius pectinatus, *Ag.*	9
	Fish tooth	7
	Helodus, sp.	7
	Palæoniscoid Fish	9
	Strepsodus, sp.	5, 9

Carbonaceous Series and Fell Sandstones.—In the lists of localities and fossils we adopt the same plan of numbering as before. As a matter of fact all the localities in the list should probably be referred to the Carbonaceous Series.

Fell Sandstone Localities.

14. Swallow holes, 300 yards sonth of head of Carry Burn, and two and three-quarters of a mile north of Kielder Head: grey limestone.
15. Old limestone quarries at the head of Bateinghope Burn.
16. Near head of Wainhope Burn, one mile and a quarter north of Wainhope: impure limestone between coal seams.
17. Buck Burn, three-quarters of a mile north-west of Willow Bog.
18. ,, just on the north side of the road: nodules of hard marl in clay shale.
18*a*. Stream E.S.E. of Bloody Bush, by the road-side: marl band (B.N. Peach; plants by R. Kidston). Apparently the same locality as No. 18.—C. T. C.
19. Lewis Burn, ¼ mile above the Low Long House.
19*a*. ,, Below the Low Long House: impure limestone. (B.N. Peach; plants by R. Kidston).
20. ,, ⅛ mile S.W. of Lewisburn House: hard grey shales.
21. Stream, a little over one-eighth of a mile south-west of Mounces: impure flaggy limestone in shale.
22. East side of Lewis Burn, half-mile south-west of Lewisburn House: thin calcareous sandstone.
22*a*. Same locality as 22: hard flaggy shale.
22*b*. Same locality as 22: impure limestone.
23. Rigend Burn, 2¼ miles N.E. of Rigend: calcareous sandstone.
23*a*. Same locality as 23: ferruginous limestone nodules in dark shale.
23*b*. Same locality as 23: dark clayey shale with ironstone nodules.
24. Lewis Burn, a little over one hundred yards below Lewisburn Colliery: sandy shales below coal seam.

25. Lewis Burn, at Lewisburn Colliery: sandstone over coal seam.
26. Lewis Burn, three hundred yards above Lewisburn Colliery: flaggy impure limestone in shale.
27. Lewis Burn, rather over two hundred yards below Lewisburn Colliery: sandy shales below coal seam.
28. Lewis Burn, one hundred yards above the old Lewisburn Bridge.
28*a*. Lewis Burn, specimens in the Tate Collection, Alnwick (R. Etheridge).
29. East bank of the Tyne, 300 yards S.E. of Wellhaugh: dun-coloured limestone.
29*a*. Same locality as 29: thin impure limestone in sandy shale.
30. At and near foot of Belling Burn: dun-coloured impure limestone.
31. Plashetts Burn, three-quarters of a mile west of Wainhope: dark sandy shale below sandstone.
31*a*. Plashetts Burn, about 1 mile above the station: soft coaly shale (B.N. Peach; plants by R. Kidston).
32. Belling Burn, one hundred and sixty yards above level mouth of Plashetts Colliery: grey sandy bed above coal.
33. Old quarries by side of old drove road between Wainhope and Bellingburn Head: blue limestone.
34. South-western bank of sike, a little over a quarter of a mile north-west of Bellingburn Head: yellow calcareous sandstone.
34*a*. Same locality as 34: shale below sandstone.

Fell Sandstone Fossils.

		No. of Locality in foregoing List.
Plantæ	Calymmatotheca bifida, *L. & H.*	17, 23*a*, 23*b*, 27, 31*a*
	Cardiocarpus Gatbieri, *Geinitz*	19*a*
	Crossochorda carbonaria, *Kidston*	22
	Lepidodendron?	27
	Lepidostrobus comosus *L. & H.*	27
	,, fimbriatus, *Kidston*	20, 24, 27, 28
	,, variabilis, *L. & H.*	22*a*
	,, n. sp.	19*a*
	Lepidophyllum, sp.	27
	Pinnularia-like (?)	27
	Rhacopteris subcuneata, *Kidston*	22*a*
	Sarocladus antecedens, *Kidston*	27
	Schutzia, sp.	19*a*
	Sphenopteris, sp.	23*a*, 24, 27
	Spiropteris, sp.	27
	Stigmaria ficoides, *Brong.*	17, 25, 27, 32
Actinozoa	Alveolites, sp.	19*a*
	Aulopora, sp.	15
	Cyathophyllum?	14
	Lithostrotion cæspitosum, *Mart.* (= L. Martini of *M. Edw.*)	15
	,, junceum, *Flem.*	14, 15, 33
	,, McCoyanum, *M. Edw.*	15
	,, sp.	29, 30
	Monticulipora (Chætetes) tumida *Phil.*	19*a*, 21, 22*b*, 26
	Syringopora genioulata, *Phil.*	15
	Zaphrentis cylindrica, *Scouler*	15
	,, Phillipsi, *M. Edw.*	29*a*
	,, ?	14
Echinodermata	Archæocidaris (spine)	22, 26
	Crinoid ossicles	29
Annelida	Serpulites, sp.	23*b*
Crustacea	Beyrichia arcuata, *Bean.*	27, 32
	,, craterigera, *G. S. Brady*	Plashetts.
	,, sp.	23*b*
	Beyrichiopsis fimbriata, *J. & K.*	Plashetts.
	,, subdentata, *J. & K.*	,,
	Crustacean remains	30

		No. of Locality in foregoing List.
	Cytherella, sp.	23*b*
	Kirkbya, sp.	32
	Leperditia subrecta, *Port.*	27
	,, sp.	20, 26, 31, 32
	Phillipsia gemmulifera, *Phil.*	34
Arachnida	Eoscorpius, sp.	19*a*, 23*b*
	Scorpion remains	28
Polyzoa	Ceriopora interporosa, *Phil.*	21, 22*b*, 23, 26
	Fenestella membranacea, *Phil.*	26, 29*a*
	,, oculata, *Phil.*	22*b*, 26, 29*a*
	,, tenuifila, *Phil.*	26
	,, sp.	21
	Rhabdomeson gracile, *Phil.*	21, 26, 29*a*
	Vincularia raricosta, *McCoy*	29*a*
Brachiopoda	Athyris ambigua, *Sby.*	19*a*, 34*a*
	Camarophoria crumena, *Mart.* (? Rhynchonella pleurodon of the English lists)	19*a*
	Chonetes laguessiana, *McCoy*	34*a*
	Cyrtina septosa, *Phil.*	32
	Discina nitida, *Phil.*	19*a*, 23*b*
	Lingula, mytiloides *Sby.*	22*a*
	,, squamiformis, *Phil.*	19
	,, sp.	23*b*, 24, 27
	Orthis resupinata, *Mart.*	23*b*
	Productus, carbonarius, *De Kon.*	34*a*
	,, giganteus, *Mart.*	15, 29, 30, 33, 34
	,, punctatus, *Mart.*	19*a*, 29*a*, 30
	,, scabriculus, *Mart.*	23, 26
	,, semireticulatus, *Mart.*	19*a*, 24, 34, 34*a*
	,, undatus, *Def.*	34, 34*a*
	,, sp.	15, 22*b*
	Rhynchonella pleurodon, *Phil.*	23, 23*a*, 24, 26
	,, pugnus, *Mart.*	34*a*
	Spirifera duplicicosta, *Phil.*	22*a*
	,, laminosa, *McCoy*	21, 22, 34
	,, striata, *Mart.*	28*a*
	,, trigonalis, *Mart.* (= S. bisulcata, *Sby.*)	29
	,, sp.	34*a*
	Spiriferina cristata, *Schloth.*	34
	Terebratula (spat of)	23*b*
Lamellibranchiata	Anthracomya Scotica, var. *Eth. jun.*	31*a*
	Avicula bicostata, *McCoy.*	27
	Aviculopecten cœlatus, *McCoy*	19
	,, concavus, *McCoy*	33
	,, duplicicosta, *McCoy*	19*a*
	,, incrassatus, *McCoy*	34
	,, interstitialis, *Phil.*	19*a*
	,, Jonesii, *McCoy*	23*a*
	,, planicostatus, *McCoy*	19*a*
	,, segregatus, *McCoy*	19*a*
	,, villanus, *De Kon.*	19
	,, sp.	23*b*, 27
	,, n. sp.	19*a*
	Cypricardia, sp.	16
	Dolabra, sp.	23
	Edmondia sulcata, *Phil.*	19*a*
	,, unioniformis, *Phil.*	19*a*
	Modiola divisa, *McCoy*	19*a*
	,, quadrata ? *Sby.*	23*b*
	,, sp.	31

		No. of Locality in foregoing List.
	Myalina crassa, *Sby.*	23*a*
	,, Verneuili, *McCoy*	19
	,, sp.	21, 24, 26, 27
	Nucula, sp.	21
	Nuculana (Leda) attenuata, *Flem.*	16, 19*a*, 21, 24, 32
	,, ,, Sharmani, *Eth. jun.*	19*a*
	Pinna flexicostata, *McCoy*	34
	Pteronites angustatus, *McCoy*	19*a*, 26
	,, Thomsoni, *Port.*	24
	,, sp.	18
	Sanguinolites, variabilis, *McCoy*	16, 22*b*, 28*a*
	,, sp.	23*a*
	Schizodus (Axinus) axiniformis, *Phil.*	18*a*
	,, ,, sp.	18, 20
Pteropoda	Conularia quadrisulcata, *Sby.*	19, 22*a*
Heteropoda	Bellerophon apertus, *Sby.*	28*a*
	,, decussatus, *Flem.*	21, 28*a*
	,, ,, var. striatus, *Flem.*	19*a*
	,, hiulcus, *Sby.*	19*a*, 24
	,, tenuifascia, *Sby.*	19*a*, 29
	,, Urei, *Flem.*	19, 21, 23*b*
	,, sp.	23*a*, 34*a*
Gasteropoda	Euomphalus acutus, *Sby.*	19*a*
	Flemingia (Trochus) hisingeriana, *De Kon.*	18*a*
	Loxonema rugifera, *Phil.*	29*a*
	,, curvilinea, *Phil.*	18*a*, 19*a*
	,, Lefebvrei, *Lev.*	19*a*
	,, elongata, *De Kon.*	28*a*
	,, like imbricata, *Phil.*	18*a*
	,, sp.	18*a*, 19, 23*a*, 24, 32
	Murchisonia verneuiliana, *De Kon.*	18*a*, 19*a*, 23*b*
	,, sp.	19, 24
	,, n. sp.	19*a*
	Narica, sp.	23*b*
	Natica elliptica, *Phil.*	19*a*
	,, sp.	19, 21
	Naticopsis ampliata, *Phil.*	18*a*
	,, plicistria, *Phil.*	18*a*, 19*a*, 20, 23*a*, 23*b*, 24, 28*a*
	Operculum of a gasteropod	24
	Platyschisma? (or Trochus)	18*a*
	Pleurotomaria Griffithii, *McCoy*	19
	,, serrilimba, *Phil.*	24
	,, vittata, *Phil.*	18*a*
	,, Yvani, *Lev.*	18*a*, 19*a*
	,, ,, var. nov.	18*a*
	,, sp.	18, 23*a*
	Scalites (Actæon?) fusiformis, *De Kon*	19, 21
Cephalopoda	Cyrtoceras Gesneri, *Mart.*	22*b*, 30
	Discites, sp.	19*a*
	Goniatites, sp.	29, 30
	Nautilus, sp.	26
	Orthoceras, sp.	19*a*, 21, 34*a*
Pisces	Fish tooth	27
	Helodus, sp.	23
	Petalodus, sp.	26
	Strepsodus, sp.	23*b*

CHAPTER IV. CARBONIFEROUS CONTEMPORANEOUS IGNEOUS ROCKS.

The Carter Fell Tuff, or Ash.—This is only seen distinctly in one small exposure on the English side of the Border, at a point about 75 yds. within it and close to the base of the basalt. Here it is of much of the same character as on the Scottish side: no basalt fragments have been noticed but fine grained micaceous sandstone pieces are common, and there is also a fine dark grey rock of doubtful character (palagonite?). It is possible that the tuff belongs to a volcanic neck. In England the exposure occurs at the top of the Cementstone Series.

The Carter Fell Basalt.—This rock makes a green feature on the east and south sides of the north point of Carter Fell. The thickness on the north side of the east-to-west fault mapped averages probably at least 50 or 60 ft., on the south side perhaps half this. The rock is a sound massive dark-blue basalt, as perhaps it should rather be called dolerite, free as far as known, except in one or two places, from any abundance of amygdaloidal cavities, and with prominent porphyritic crystals of felspar. In these respects it offers a great resemblance to the Lumsdon Law Basalt (108 S.E.) and an equal contrast to the cotemporaneous beds of Cottonshope, &c. (108 S.E.).

In the following description of a microscopic section I have been kindly helped by Mr. J. J. H. Teall. The felspars are trielinic and belong to two periods in the process of consolidation: (1) large felspars with inclusions and zonal structure, showing sections of approximately equal dimensions in the different directions; (2) smaller felspars usually giving lath-shaped sections—inclusions rare. Olivine in crystals and grains, colourless, more or less serpentenized, abundant. Some crystals large. At times contains so many inclusions of magnetite that they may nearly equal in bulk the Olivine substance itself. Augite, brown, in small crystals and grains; the inclusion of well developed crystals within the felspar proves that the augite consolidated before the felspar. The black opaque mineral, magnetite or ilmenite, occurs in fair-sized patches scattered uniformly through the rock both as inclusions and otherwise. It is frequently penetrated by the points of the crystals of felspar, and as seen in plane section sometimes entirely encloses portions of it. There is also apatite in narrow acicular prisms; and a small amount of isotropic interstitial matter, rendered turbid by indistinct flecks and granules, (microfelsite of Rosenbusch).

There are no satisfactory sections showing either the top or bottom of the bed, and no evidence is thus obtainable to help to decide whether it be intrusive or not. There is no doubt though that it occurs in the form of a sheet rudely parallel to the bedding

planes of the adjacent rocks: on the north side of the east-to-west fault the horizon appears just at the base of the Fell Sandstones: on the south side there is a strong sandstone between it and this base. Whether this means that the bed has here altered its horizon and is consequently intrusive, or that the strong sandstone is a bed which was not developed in the area north of the fault is uncertain. It is coloured in the map as contemporaneous, because it was so taken on the Scottish side which was first mapped, but in view of the contrast with the Cottonshope contemporaneous beds (108 S.E.) some will perhaps prefer to consider it intrusive.

CHAPTER V. INTRUSIVE BASALTIC DYKES.

Of the Basaltic Dykes now to be described eight show a general west-north-west direction, which is also a common direction through the rest of the north of England and south of Scotland. Good reasons for considering this class of dykes to be of Tertiary age have been given by Prof. A. Geikie* and others. The larger dislocations of the district seem rather to run east-north-east, but smaller ones parallel to the dykes and often very near them are also common. In at least one case it is clear that the dyke itself has been crushed by such a parallel disturbance. In others the dyke substance itself may not be affected, and we are left in doubt as to whether the disturbance took place before or after the intrusion. The tendency to crack in the earth's crust along the directions of the dykes may have often begun before or at the same time as the intrusion, and may have determined their direction.

Amygdaloidal cavities are more or less common in all the dykes, and are sometimes rather large; but owing to their regular spherical shape they run but little risk of confusion with those of contemporaneous traps, which usually show elongation in one direction in accordance with the local flow, and are also often bent and branched.

In no case has any appearance been detected at the sides of mechanical disturbance effected by the intrusion.

Dyke in the Burn West of the Trouting.—This dyke crosses the burn in a direction slightly south of east and makes a waterfall. Near the middle of the fall it is underlain by shale for a horizontal distance of 1 ft., but the vertical cuts through sandstone at the sides of the fall are quite distinct. The breadth is about 4 ft. The rock is an even medium grained basalt and shows no porphyritic felspars: it contains regular spherical calcite amygdules—the larger ones averaging about $\frac{1}{20}$ in. in diameter—in greater abundance than usual in the dykes. The side exposed in the fall shows the blistered nodular look not uncommon in dyke-sides. Crossing below the dyke, and at distances respectively of 66 and 86 yds., are weak faults running parallel.

A block of the dyke is seen 25 yds. east of the burn, but not the slightest trace of it could be found crossing the strong sandstone brow of the Trouting.

Kielder Head Dyke.—Hand specimens of this dyke show prominent porphyritic crystals of felspar, a character in which it stands alone among the dykes in this sheet. Perhaps it is also slightly less amygdaloidal than them as a rule. It has been traced

* *Proc. R. Soc. Edinb.*, vol. iv. p. 71, 1867; *Rep. British Assoc.* for 1867, Sections, p. 49; *Proc. R. Phys. Soc. Edinb.*, vol. v. p. 219, 1880; *Trans. R. Soc. Edinb.*, vol. xxxv. Pt. 2, 1888.

across the map a distance of four and a half miles, and keeps throughout a very uniform west-north-west direction. A microscopic section is thus described by Mr. J. H. Teall in a letter to me. The prevailing constituent is plagioclase felspar. Olivine, augite, and magnetite occur in about equal proportions. The olivines are large but much broken and fissured: alteration into serpentine has taken place along the margins of the cracks, but a fair amount of the original mineral remains. Augite occurs in the form of minute crystals (rare) and crystalline grains (common): under ordinary light it may be distinguished from the olivine by its faint brown tint and fresh appearance. Magnetite is evenly and abundantly scattered through the rock, and rarely shows any trace of alteration. Apatite occurs in the form of long clean needle-like prisms. A little clear slightly brownish glass may be detected here and there; but it is somewhat rare.

Perhaps the best exposures are in the two branches of the sike marked 1 mile or more up the east side of Scalp Burn. Following the dyke from north-west to south-east we notice the following indications. In the cleugh running north-east from the top of Peel Fell the crossing place can be localized to within a few yards by the tracing up to it of various loose pieces of the rock and their cessation above it. It should be said here that the drift along the whole course of the dyke is of local origin, and there is no danger of being put on a false scent by far travelled basalts of similar aspect. About 380 yds. beyond this cleugh, and again a little over half a mile beyond, is much angular basalt of the characteristic kind and evidently near place. The next exposures are the two on the east side of Scalp Burn already alluded to. After this it is readily traceable for some distance, either by suspicious gaps in the freestone scars it has to pass through, or by finding the rock in situ. This last is the case a yard or two east of the track leading north from Kielder Head. 200 yds. beyond the track it forms first a feature facing south-west and then a green ridge. On the east of White Kielder it forms a green ridge or feature facing the south: the sandstone features are traceable close up to either side of the ridge and do not appear thrown. In the sike on the north side of Rigend Burn next to the east margin of the Map the dyke is again seen quite clearly.

The Deadwater Dykes.—The south of these crosses the burn about 180 yds. above the bridge. It is a fine even-grained basalt and shows no porphyritic felspars. On the north side it is much decomposed. The direction is about east-south-east. On following along in this direction it is again seen near the head of the sike first met with: on the north side the rock is again decomposed as in Deadwater Burn. The thickness is perhaps 9 or 10 yds. There are spherical pinhead vesicles filled with calcite. It is again seen in place about 80 yds. east of the sike.

The north dyke is seen only very obscurely in Deadwater Burn, just where the track leading north crosses the burn. It crosses the sike next on the east about 130 yds. above the south

dyke, to which it is closely connected in character and direction. About 230 yds. beyond the sike it is again seen, and the loose pieces near suggest that possibly we may have here a union of the two dykes. Further south-east the dyke is marked by loose angular pieces at various localities. At the height of the pieces found this fellside is practically free from foreign drift, and so we can have confidence that the pieces are not derived therefrom.

Dyke crossing Kielder Burn half a mile above Kielder Castle.—This is seen on the west bank of the burn with a width of about 6 ft. The impure limestone through which it passes is for a foot or more from the sides marked by obscure division lines—probably cleavage—parallel to the sides. The rock is a fine even-grained basalt and shows no porphyritic felspars. Spherical calcite amygdules occur in abundance, but rarely exceed $\frac{1}{40}$ in. in diameter. In a north-west direction nothing is known of the dyke, but to the south-east it has been traced more than two miles. First of all it appears obscurely in a sike half a mile west-south-west of Grey's Pike. Then it is seen in the purple and yellow clays near the head of a burn south of Grey's Pike, and then in Plashetts Burn a third of a mile below Wainhope. In this last exposure the width is at least 9 ft. and it forms on either side of the burn a gulley in massive sandstone. It is more decomposed than in Kielder Burn, especially east of the burn where it has been dug by the Wainhope shepherd for rubbing stones for the hearth. 3 yards north of the dyke is a weak fault breccia, and 20 yards south a stronger one, both running parallel to it.

The Kielder Viaduct Dyke.—This is best seen on the east bank of the Tyne 120 yds. above the viaduct. It occurs here in two divisions with a breccia between: the north division averages 4 ft. in width, the south one from 4 to 5½ ft., and the breccia from 4 to 5 yds. Both divisions consist of the same fine-grained Basalt, and contain spherical calcite amygdules which weather hollow with a rusty lining. There is no marked difference in character at the sides, unless it is that the amygdules are slightly more numerous at the inner sides which face one another. The inner sides are also for the width of a few inches from the breccia kaolinized and converted into a stiff yellow clay.

The chief fragments in the breccia are of sandstone, greenish brown or greenish grey: their size is sometimes considerable, even up to 4 ft. long. Next in frequency come green and black shales, and after these basalt. The basalt pieces are often 2 or 3 in. in length, are fairly angular, amygdaloidal and always decomposed. They are distributed pretty uniformly throughout all the breccia. Their occurrence shows that the breccia is a friction-breccia formed after the intrusion of the dyke. With this supposition agrees the fact that the most amygdaloidal portions—probably once in the centre of the dyke—are on the inner sides of the divisions. On the south side of it there are two parallel faults at distances of about 36 and 60 yds. respectively: they have each a downthrow to the north of about 2 ft.

On the north side of the north part of the dyke the adjacent sandstone is in one place converted into a hard glistening quartzite, and the shale into pencil shale, partly bleached. On the south side of the south division there is no evident alteration.

The general direction is perhaps 30° west of north. About 3 ft. north of the north division is a 2 or 3 in. string of very fine grey porcelain-like basalt, with a marked twist in its course.

West of the Tyne the dyke is seen first in a slack 200 yds. west-north-west of the Ordnance Station 860. Within a distance of 130 yds. of the Catcleugh Burn exposure it makes a thin green ridge. In the burn the width appears to be 3 or 4 yds. After this there is no certain exposure of it up to within 10 or 12 yds. of the Bell's Burn, but it can be traced with confidence by the gaps in the various sandstone scars. The exposure by Bell's Burn is in a small sike that comes in from the east.

The Bellingburn Head Dyke.—This is visible a few yards within the edge of the adjoining Map (108 S.E.), and has been prolonged into this a short distance under Boulder Clay. The rock is a fine even grained slightly amygdaloidal basalt, and runs in a north-east direction. It cannot continue far into this Map, unless its course be altered, for one of the levels in the Plashetts colliery is driven 100 yds. north of the bend in Belling Burn next below Bellingburn Head, and did not meet with it.

Dyke on Gowanburn Moor.—The exposure on either side of the burn shown on the map is ill defined, and both thickness and direction are doubtful. The most probable direction is north-east, *i.e.*, about at right angles to most of the dykes. The rock resembles that of the Kielder Viaduct dyke, but perhaps is rather more coarse in grain.

Dyke three-quarters of a mile North-west of Mounces.—This is exposed in the course of the track that starts from the road about 300 yds. above the wood south of Wellhaugh Moor. It forms the roadway of the track 16 yds. south of the burn, but is only very poorly seen. The width is perhaps 2 yds., and the direction very slightly south of east. Sound hand specimens are hard to procure: they show many small soft serpentinous looking specks and streaks in a rock which otherwise closely resembles most of the dykes of the sheet. There are many small amygdaloidal cavities: some of them are filled with calcite, but others, even when some distance off a weathered surface, are empty except for a thin lining of soft dark green earth.

Dyke East of Low Long House.—The best exposure occurs in the north to south cleugh next east of Lewis Burn at a point about 240 yds. above the foot of the cleugh. It is about 10 ft. wide and cuts through black shale without bleaching or sensibly hardening it, or affecting the dip. The direction is nearly east to west. The junction on the south side of the dyke is very distinct: both in the basalt and the shale there are obscure division lines running parallel to the junction for a width of 6 or 8 in. on either side. The hade is slightly north, and there are prisms starting at right angles to it through the dyke. The

dyke rock is in the middle a rather coarse grained basalt very even in texture and with no porphyritic felspars: here and there are a few calcite amygdules, up to the size of a pea. At the side it is much finer with a grey porcellanous aspect.

It is next seen at various places between the two east and west sikes marked in the Map. In the most north one it passes close by the mouth of the old level, and was found to have burnt up into cinder the supposed Plashetts seam which the level was started to work. In a bend 200 yds. above the level it appears in a very rusty looking concretionary form. Thence it crosses to the north side of the sike and is seen distinctly 70 or 80 yds. away to the east-north-east.

The Harrett's Linn Dyke, Lewis Burn.—This is seen on the east side of the burn half a mile above Low Long House. It occurs rudely parallel with and close on the south side of a large fault. The rock is so decomposed that the colour closely resembles the soft ferruginous freestones it cuts through. It is only traceable for 8 yds., and the thickness is only from 6 in. to 1 ft. Still it is of some interest, for a thin slice showed on microscopic examination distinct signs of fluxion structure: the felspars being arranged with their longer axes prominently parallel. It is not known for certain what relation these axes have to the sides of the dyke but we may probably judge they are parallel.

The Lewisburn Dyke.—The wide dyke which crosses the south-east corner of the map is thus named by Professor Lebour.* It is presumed to be the same as the one at High Green (108 S.E.) described by Mr. Teall.† For the most part it consists of a rather coarse even-grained basalt—decidedly coarser than any other dykes in the sheet. A microscopic section obtained from the railway cutting south of Plashetts is thus described by Mr. Teall in a letter to me. A granular rock composed of felspars giving lath-shaped sections: monoclinic pyroxene in irregular grains and plates, rarely showing definite crystalline boundaries, and possessing pinakoidal as well as prismatic cleavages (? diallage): what appears to have been rhombic pyroxene, now altered into a kind of bastite, and traversed by opaque veins of iron oxide: and magnetite or ilmenite in irregular plates and grains.

The general direction of the dyke is east-north-east. Where it first enters the Map from Lewis Burn it is scarcely recognizable, but after 100 yds. it forms a feature facing the north, which continues for about half a mile until obscured by Boulder Clay. For two miles its course is entirely hidden by drift, alluvial gravels, &c., and we have through this obscure ground only marked it doubtfully and without colour. We have little doubt however that it does crop out under the later deposits for at all events a considerable distance, for boulders of it are common south-east of the line drawn, especially in the burns west of Mounces and near the head of the plantation south-west of

* Outlines of the Geology of Northumberland, 1878, p. 50.
† *Quart. Journ. Geol. Soc.*, vol. xl. pp. 240–242. 1884.

Mounces. Now the ice markings in the district indicate a carry to the east-south-east, and it is therefore unlikely that boulders in such abundance should have come to these localities from present exposures: we may better consider them derived from old exposures to the north-east now hidden under Boulder Clay.

It appears again distinctly 250 yds. east of the Tyne. The section in the railway cutting shows a width of about 35 yds. The junction on the south is not seen; on the north it cuts through sandstone and sandy shale which is rather hardened and bleached. The side hades a little to the north and there is a set of planes starting at right angles from it which go across to the other side. Vesicular cavities are common and sometimes attain the size of a pea. Beyond the cutting it forms for one third of a mile a strong green ferney ridge or feature facing south. Then for 200 yds. it is covered by Boulder Clay, but the covering is not very thick, and the feature of the dyke continues visible under it, until it emerges again a few yds. east of the track leading from Plashetts Station to the Law.

The section in Pot Burn, the burn west of Wind Hill, shows two main branches of the dyke, at a distance from one another of about 40 yds. Both of these are isolated by Drift from the nearest exposures east and west, and it is impossible to say where they unite, or even if they do so at all at the surface. The south branch however shows, on the west side of the burn, indications of again splitting up into two branches, and is also rather less near the straight line that joins the nearest exposures east and west, and so it has been mapped as a subordinate dyke and has not been continued far west of the burn. The divisions of this branch appear a few yards off the burn on the west side: the sedimentary rock between consists of soft white sandstone with brown specks, and grey shale, perhaps slightly bleached by the intrusion.

A little lower down the west bank, nearer the stream, the two divisions have united, and the rock consists entirely of basalt, but not always of the same kind. About in the middle it is in great part much finer grained and less amygdaloidal—differences which make themselves clear by the smooth straight faces and sharp joints of the weathered portions, when compared with the soft decomposed exfoliating rough surfaces of the coarse rock. The fine rock penetrates the coarse in tongues and is mixed with it very variously. There is no large distinct section, but plenty of small ones may be obtained to show the relations of the two to a certain extent. There are many fragments of the coarse within the fine, of a length from 2 in. or more down to the smallest speck, and generally with sharp angles. There is no mineral or cavity between the varieties, and, as the fine rock wrapping round the fragments gets finer and finer as their edges are approached, we are compelled to suppose that it has at some time been intruded into, and caught up fragments of the coarser basalt. In one instance a fragment itself was noticed to get finer on one of its sides.

There are also occasionally long narrow stripes of still finer rock in the including basalt, which gives at first an impression of

flow-structure. But on examining a microscope slide taken across one of these fine bands it seemed rather due to a thin crush line going through the rock: it contains a narrow string of quartz specks in the centre and on the sides of this are specks of iron-pyrites. In one place too there is a weathered jumble of the different varieties and pyrites which closely resembles an ordinary fault-breccia.

Near the north side of the dyke on either side of the burn some of the fine rock is seen again, but the sections are not good. On the south side the rock seems all of the coarse kind.

The north dyke is about 25 yards wide, rather less than the undivided south one. It consists throughout of the coarse rock. About 65 yards north of it there is a parallel fault. Both dykes form ridges on the steep east bank of the burn.

The exposure in Belling Burn shows but one dyke, and this is to a large extent covered by the stream. North-east of this it can be traced to the edge of the Map by a green feature facing south-east: it is somewhat obscured on the spot by a series of slacks (Glacial probably) crossing at right angles, but shows plainly in the distance from the east slope of Wind Hill.

The Law Dyke.—The only exposure known is at a point about a quarter of a mile north-north-east of the Law. The rock is a fine even-grained basalt without any porphyritic felspars, and contains many spherical vesicles averaging $\frac{1}{20}$ in. in diameter. The vesicles are in general filled with calcite, but sometimes with banded milky blue agate. The hade appears south-south-west. The width may not be more than 1 yard. It is only traceable for 12 or 14 yards, and on proceeding 40 or 50 yards north-west, in its apparent direction, we come to a bare freestone dip slope without any sign of it.

CHAPTER VI. FAULT-BRECCIAS, AND MINERALS OCCURRING THEREIN.

The fault-breccias are not in general largely infiltrated with spar. Calcite and quartz are the commonest cements. The latter has nowhere been noticed in thick ribs, though very common in minute strings in the freestones or as a glaze to their slickened faces. Calcite is, as we might expect, particularly common where the break passes through limestone: among other places where it may be seen are Oakenshaw Burn by the house, in the Belling Burn a quarter of a mile above the foot, and the burn close to the Scottish Border north of the Oakenshaw Burn road. Barytes occurs mixed with it in thin strings in the high dipping beds 30 yds. or so above the old bridge above Kielder Castle on the east side of the burn, and in the breccia in Plashetts Burn three-quarters of a mile below Wainhope.

In no case are the breccias infiltrated with useful mineral to such an extent as to be of any practical worth. The brown oxide of iron is common in very thin strings or as a stain, but never occurs in large quantity. No lead ore has anywhere been noticed by me, but it is recorded as occurring in Belling Burn a little above the railway, in the map accompanying Nicholas Wood's paper "On the Upper and Lower Beds of coal in the counties of Northd. and Durham."* and also near the Holy Well a quarter of a mile east-north-east of Otterstone Lee in the Memoir of the Revd. John Hodgson (vol. i. p. 146). It is also stated by the shepherds that lead has been found in Oakenshaw Burn about 300 yards above the house, but I do not know on what authority.

Scattered crystals of Zinc Blende, getting up to ¼ in. in length, occur in calcite strings at the south side of Oakenshaw Burn some 350 yards west-south-west of the house. The strings appear to run north-west, but they are close to where an important east and west fault should pass and are perhaps subordinate to it.

In Plashetts Burn three-quarters of a mile below Wainhope there is a thick fault breccia running north-east which contains zinc-blende in rather more abundance. The width of it averages perhaps 6 feet, and it consists mainly of "dowk,"† and fragments of shale and sandstone. In some places there is a breccia composed of fragments of a hard fine grained sandstone, the cavities between which are filled with calcite and barytes speckled with numerous small crystals of zinc-blende: occasionally the breccia itself occurs in a fragmental form, a fact which indicates at least two periods of movement along the break. Iron-pyrites occurs in the crush-clay in the form of small irregular nodules often showing crystalline faces on the outside.

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* *Trans. N. Eng. Inst. Eng.*, vol. xi. pp. 101–137.

† Clay formed out of crushed shale.

CHAPTER VII. GLACIAL BEDS.

Foreign boulders occur very plentifully in most of the Boulder Clay west of a line which runs rudely from one third of a mile east of Deadwater to Plashetts Colliery. East of this, and perhaps also a little on the west side in the south part of the sheet, they get rarer, and in the Scalp, White Kielder and Riggend Burns, and the heads of Dry Burn and Belling Burn, seem quite absent. Most of them show evident signs of their long journey in their small size, extremely rounded outlines and excessively striated surfaces—characters in which they contrast strongly with the local freestones which have been incorporated in the clay at a later stage. The matrix in which they are embedded consists in general of a tough dark grey, brownish grey or blue clay, which is quite impervious to water.

A list of the foreign rocks which have been noticed is given at the end of this chapter. It seems that at all events in some cases they cannot have come from the parent localities by direct routes; *e.g.*, the Criffell Granite exposure lies south-west of this sheet yet the glacial features, rock striations, and disposition of the larger masses of the clay, point to a south-east carry of the foreign clay.

The most wide-spread and thick deposits occur on the west and north sides of the valleys, *e.g.*, in the valleys of Plashetts Burn south of Wainhope, of the Belling Burn, Rigend Burn and Lewis Burn: a fact which in accordance with the rule in other districts points to the drift having come in the main from the north-west. The hills on the west side of the Tyne are completely swathed in foreign drift even up to their summits: this is seen well at the head of Catcleugh Burn (Kielder Station) at a height of about 1,250 ft., and on Caplestone Fell half a mile slightly north of east of the Ordnance Station 1,555 at a height of about 1,400 ft.

In the Kielder Valley foreigners are not traceable much beyond one mile north-east of Kielder Castle. About three-quarters of a mile above the Castle on the north-west side of the burn there are some good sections showing many Silurian pebbles, and some of porphyritic basalt and dark red sandstone. Further in the hills the clay is often a chocolate red colour, a colour doubtless due to the variegated grey and red clays, &c., which occur in the Fell Sandstone Series of the Scalp Burn, White Kielder, &c., and the boulders enclosed are mostly freestone.

In Dry Burn a small agate pebble was found two-thirds of a mile above Wainhope where the stream runs through Boulder Clay. This is some distance further east than any other foreigners noticed in this valley.

There are no indications of boulders of the porphyritic basalt dyke, in the north-east of the Map, having anywhere been carried north-east from it. Just at, and 300 yds. above, the foot of the north-north-west cleugh next east of Kielder Head there are several boulders of it, but they lie a quarter of a mile south-west from the nearest exposure.

Large blocks belonging to the wide Lewisburn dyke are particularly common north-north-west of the Law and half a mile west of Emmethaugh. The nearest exposures lie north and north-west.

Coal pebbles are excessively common in the clay on the south side of Belling Burn 200 yds. below Bellingburn Head and near the head of Dry Burn. This is only what one might expect from the number of coal seams in the neighbourhood.

The greatest known thickness of the clay is about 120 ft. This occurs on the west side of Belling Burn near Plashetts Colliery. The working level of the colliery started in beds a little below the coal, but, after being driven 40 yds., it got into Boulder Clay and continued in it for about 200 yds. in a north-north-west direction before the rock was reached again. The water level starts in clay and keeps in it for nearly 400 yds. before it reaches rock. It seems clear that these levels must be driven in the old preglacial valley of the burn, which is now quite filled with clay. The part of the working level driven in clay is very dry and shows no gravel or sand bands. The section on the south side of Oakenshaw Burn a little below the old Toll Bar shows about 100 ft. of uniform stiff brownish grey Boulder Clay. In the old pit-shaft one-third of a mile slightly west of south of the bridge at the foot of Lewis Burn a thickness of nearly 57 ft. was proved. From these thicknesses it varies down to the thinnest covering.

The parts of the foreign clay near the surface often show a gradual change of colour from dark grey or blue, to brown and yellow, and of consistency from a tough water-tight to a somewhat porous sandy character. I have noticed the change particularly clearly in the sike-head that passes by the camp on Wellhaugh Moor. The change is no doubt due to the gradual peroxidation of the iron salts of the clay, and, the mechanical washing away of the finer material from the top by rain. There are many sections which show a deposit near the top intermediate in character between sand or gravel and the normal Boulder Clay. Whether the difference between the upper deposit and the lower is original, or acquired subsequently in some such manner as described, it is usually, in default of clear sections, impossible to say with certainty. Should it be original the upper part must be looked upon as a later and more local clay, formed mainly from the freestones of the district when the climatic conditions were not so severe as formerly.

The only section noticed that showed such an upper Boulder Clay distinctly was on the south-east side of Caplestone Fell, on the north bank of the sike one-eighth of a mile east-north-east of the Ordnance Station 1040. Unfortunately the section was

subsequently obscured by a landslip. The rocks in the upper clay here consist of freestone. The clay in which they are embedded is yellow and rests irregularly on a dark grey clay which contains less freestone: it has in one place a tongue running obliquely down into the lower clay, and is evidently rather more porous than it, there being a faint wet line at their junction. The height is a little over 1,000 ft. Both above and below in this sike, and also in the sike 160 yds. north of it, there are many big freestone blocks scattered about, which of themselves also suggest the presence of a later local drift.

Thin bands of sand, gravel or laminated loam are common within Boulder Clay. We may note the following instances. In the railway cutting one quarter of a mile south of Kielder Station a 3 ft. water bearing sandy loam with pebbles; about 5 ft. above this is another similar wet band 1½ ft. thick, and above this another band of softer sand perhaps 1 ft. thick. There is a good spring on the west side of the cutting 300 yds. south of the bridge and this probably comes out of one of these bands. In the section on the sike bank north of the railway a little less than half a mile west of Plashett's Station. About 100 yards above the foot of Little Burn, in the bed of the stream, 1 ft. of gravel, with stony chocolate brown clay above, and less stony dark grey clay below.

In two cases gravel is seen below Boulder Clay and resting on rock. One is on the west side of Deadwater Burn; the gravel here first appears 150 yds. above the house. It consists of 8 or 10 ft. of rounded boulders with very little arrangement. The rocks composing them are mostly, if not all, of freestone, in which respect they contrast strongly with those of the overlying clay, which are nearly all foreigners, especially Silurian. About 350 yds. above the house the thickness appears only about 3 ft. The other instance first appears on the north side of Rigend Burn, about one and a quarter mile above Rigend, and is traceable nearly half a mile. It lies under a stiff blue Boulder Clay the rocks in which seem entirely of local origin. The thickness in one place is about 10 feet. The pieces composing it are mostly freestone, the smaller ones often well rounded, but the larger somewhat angular.

There are other gravel or sand deposits marked as glacial in the Map, though they are not actually seen to underlie Boulder Clay. Their disposition does not allow one to consider them as fluviatile in the ordinary sense of the term. Deposits of this kind occur, among other places, south and east of Ferney Knowe, at Plashetts farm house, on the west side of Belling Burn on the top of the bank south-west of the colliery level. On the west side of Plashetts Burn at the north end of the wood, and again lower down on the same side of the burn, there are beds of very coarse gravel made up almost entirely of freestone. In one place the pieces get up to 2 ft. in length and are rather angular. In the tough brown Boulder Clay below are many foreigners. At the foot of Little Burn there is a considerable thickness of finely laminated sandy loam under coarse gravel and over Boulder Clay

In one place a gravel is also seen below it but not such a coarse one as that above. The upper gravel has a distinct terrace form and is no doubt fluviatile. The underlying loam is not traceable over so large an area and may possibly be glacial. An instance very similar to the last-mentioned occurs on the south side of Otterstone Lee Burn, at a point 100 yds. west of where the road crosses.

Only few perched blocks have been noticed. One conspicuous one occurs about a quarter of a mile north-north-east of the Ordnance Station 1,371 on Caplestone Fell, at a height of over 1,250 ft. It is a massive false-bedded freestone, much like the rock it rests on. The dimensions are about 9 ft. × 6 ft. × 6 ft. There is a kind of cushion between it and the rock below, formed of a few freestone boulders 6 or 8 in. long. Three others occur on the crags south of the head of Dry Burn, at a height of nearly 1,200 ft. Two of them are about 400 yds. north-north-east of the Ordnance Station 1,202 and the third 300 yds. slightly east of south thereof. They are all composed of a knobbly weathering sandstone, distinctly different from that on which they rest, which is much softer and weathers in low-lying pillowy blocks.

Some of the irregular knolls and masses of freestone which occur rather over half a mile slightly south of east of Mid Fell top, and the Haw Knowe, one mile east of Kielder Castle, may possibly be glacially transported masses.

In the north-east part of the Map, where the clay is practically all of local origin no glacial striations have been observed, but in the south-west they are common. The surfaces of the striated rock are generally smoothly polished and their edges rounded off; many of the clearest have evidently been but recently exposed by denudation of Boulder Clay. As might be expected from the way the foreign clay has swathed all the hills on the west side of the Tyne, the directions of the striæ are not guided by the varying local features, but have all a general south-east or east-south-east direction. Thus in the Lewisburn valley, general direction north-east, two capital sets occur on the fellside half a mile east-south-east of the Forks, one set pointing 42° south of east and another 22° south of east; and there is another set a mile south of these with a direction about 36° south of east. In the lower part of the Plashetts Burn, general direction north and south, striæ close by the water's edge on the west of the stream, about one third of a mile above the railway bridge, point 21° south of east. In the Belling Valley, general direction north and south, striæ on the east side of the stream, about half a mile south of the Plashetts Colliery, point 27° south of east.

In looking up the valley of the Tyne from the hill on the east side of it east of Wellhaugh Moor one cannot help being struck with the great number of banks, slacks and small burns on the west side of the valley that run rudely parallel to one another and the general course of the Tyne. They are often indicated with clearness on the shaded one-inch map. Besides the west side of the Tyne they are well seen in other places, among which

we may mention the corner between Lewis Burn and Oakenshaw Burn, the corner between Grains Burn and Needs Burn, north-west of Emmethaugh; and, on the east side of the Tyne, south-west of Gowanburn, east of Plashetts Burn, on the fellside north of the Law, and west and north of Bellingburn Head. With the exception of the last locality they are practically confined to the area in which the boulder clay contains rocks of foreign origin.

Such features are due in most part to the disposition of the Boulder Clay. Usually there is no rock to be noticed in them, or if there is it is only at their bottoms. They may consist indifferently of banks, or slacks or valleys; it is common to find a bank feature in one place developing into a valley in another, especially if a lower place, *e.g.*, west of Emmethaugh, and in the corner between the Tyne and Lewis Burn. They coincide with the features in the rocks beneath near the head of Mounces Burn, as proved in trials for the Lewisburn House Coal, but much more commonly they pass over bed after bed without regard to the strike, *e.g*, on the west side of Bellingburn Head the Piper's Cross Limestone passes three of them in a distance of less than half a mile. It is not rare to find at their extremities continuations of them formed out of rock, *e.g.*, on the south side of Catcleugh Burn (Kielder Station), on the fellside between the Kielder Viaduct and the head of the burn next east, half a mile south-east of Gowanburn, &c.

Very often there is a little wash, alluvium, or peat moss in the bottoms of the valleys, and in the map these have been traced even in places where they are very narrow, in order to represent their courses graphically. The parallelism between them is only rude and instances are by no means rare where several coalesce within a short distance. A good instance of this occurs within half a mile west of the railway between Kielder Viaduct and the signal post south of Kielder Station, and another close by Ferney Knowe.

The features on the west side of Plashetts Burn, and on the north side of Dry Burn have in general a more southerly direction than usual. Those near the head of Oakenshaw Burn on the contrary have slightly more of east in them.

The railway cutting south of Kielder Station has been made for the south part within a glacial slack, and the amount of excavation necessary thus advantageously reduced.

Foreign Boulders.

LIST of FOREIGN* BOULDERS noticed within the MAP, with some of the LOCALITIES at which they occur.

Light brick-coloured soft sandstone, of fine even grain, and with white mica flakes. South side of the Tyne 30 yds. below the foot of Catcleugh Burn. Permian?

* The gravel used as ballast on the railway is, I believe, brought from Annandale.

Dark soft red sandstone. Oakenshaw Burn 130 yds. above the old Toll Bar, Kielder Burn ¾ ml. above the Castle, Needs Burn rather over ½ mile above the foot. Permian?

Soft purple sandstone. Bell's Burn scarcely ¾ mile above the foot. Permian?

Light brick-coloured soft sandstone, with white specks up to ¼ in. long of kaolin (?) and black mica. A little less than ½ mile above the Forks (Lewis Burn). Permian?

Red Carboniferous crinoidal limestone. Oakenshaw Burn, Bell's Burn, and Needs Burn. Mr. B. N. Peach, who surveyed an adjacent portion of Liddesdale, &c., supposes this was first transported up Liddesdale from the S.W., and afterwards brought across into the Tyne.

Grey compact limestone, with bands of dark grey or brown chert. Boulders of this sort, or more commonly of the chert without any limestone attached, are very common in the Oakenshaw Burn and Lewis Burn watersheds, but in the other part of the sheet I do not remember noticing them any distance north of the foot of Lewis Burn. They are often of large size; one in the sike that runs into Oakenshaw Burn just above the bridge was noticed with a length of 4 ft. Chert bands are seen in situ close to Kershope Head (106 N.W.) within 200 yds. of the south margin of this sheet, and a dark grey chert also occurs in situ in limestone close to Cranecleugh (106 N.W.) within less than a mile of the south margin of this Map, and it is possible that similar bands may occur within the Map itself hidden under Boulder Clay, but the boulders are too abundant to be all derived from this possible source. The rock is common in situ a few miles to the west within the Scottish Border.

Bright red chert or jasper. Particularly common in the foreign drift area north of Lewis Burn foot. In one boulder a red chert band was found embedded in a rock that has the appearance of a white or light green saccharoid limestone and effervesces gently with dilute hydrochloric acid. Very common in situ near the head of the Slitrig Water, and also near Riccarton: the last locality is supposed the most probable source.

Hard compact slaty blue and purple grit, with narrow opaque white streaks and oval markings. Only one boulder noticed, in the sike on the west side of Lewis Burn south of Low Long House. Possibly stained Silurian.

Silurian greywacké and shale. Very common throughout the whole of the foreign drift area. A large exposure of these rocks occurs in Liddesdale, &c.

Basalt with large porphyritic crystals of clear felspar. Common near Deadwater. Head of Catcleugh Burn (Kielder Station). Derivation uncertain.

Uniform coarse grained basalt. Quarter of a mile south of Kielder Castle. Derivation uncertain.

Basalt with a purplish matrix and very many amygdules of calcite; generally a good deal decomposed. Head of the Cat-

cleugh Burn (Kielder Station), Bell's Burn, &c. Similar to the cotemporaneous basalt rock of Liddesdale.

Dark purple porphyrite with small felspars. Half a mile east of Kielder Castle. Derivation uncertain.

Amygdaloidal purple porphyrite. Half a mile south-west of Bewshaugh. Derivation uncertain.

Decomposing purple porphyrite, or ash (tuff), going grey green in places. The railway cutting north-east of the Law. Supposed to come from the west side of Criffell.

Breccia of fine grained purple amygdaloidal porphyrite. Sike that comes into Oakenshaw Burn from the south below the old Toll Bar. Derivation uncertain.

Agate (? out of drift). The Dry Burn by the "y" of "Dry." Derivation uncertain.

Granite with large white felspars, black mica and a good deal of hornblende; quartz, not crystallized out very prominently; bits of yellow sphene. East of Caplestone Fell at a height of 1,400 ft.; hillside east and south-east of Kielder Castle; Deadwater Burn 100 yds. above the house; and various places in Lewis, Oakenshaw, and Need's Burn. Supposed to be one of the Galloway granites.

Gneissic granite. Much the same as the above, but the mica and hornblende are arranged in distinct stripes with the whiter constituents; a little yellow sphene. Might be a Highland gneiss, but for the sphene which points to Galloway, where too it is known that much of the granite is gneissic.

Granitic rock with pink and grey felspars and porphyritic quartz crystals: reddish felstone (string?) on one side. Bell's Burn rather over half a mile above the foot. A Galloway granite?

Granitic rock much as above, but the felspars a little coarser and more rarely white. Hornblende seems more common than mica, and there are large pyramidal quartz crystals, often in twins, with their edges generally well rounded. Oakenshaw Burn 180 yds. above the old Toll Bar. A Galloway granite?

Light red fine granite or granite-felstone, with several porphyritic crystals of lighter red or grey felspar, and conspicuous pyramids of quartz. Much black mica, but never in large folia. Oakenshaw Burn, a little less than half a mile below Willow Bog. A Galloway granite?

Brown fine granite or felstone, with felspars small and quartz not prominent. Mica generally decomposing, abundant and in elongated sections. Head of Needs Burn. A Galloway granite?

Besides the above there can be no doubt from their great abundance that most of the yellow weathering limestone boulders in Needs Burn and Grains Burn must be also of foreign origin, though they might be matched perhaps with similar beds found in situ within the Map.

CHAPTER VIII. RECENT DEPOSITS.

Alluvium.—The streams have generally a rapid fall, and their flats or "haughs" are composed more of sand or gravel than of loam. The cultivated haughs often indicate well the variability of the deposit; one strip, sandy and gravelly, being reserved for turnips, another, more clayey, for grass, and so on. Perhaps the finest deposits occur in the Tyne valley between the Scottish Border and Kersey Cleugh. The name Deadwater Lakes is given to this part of the river and is perhaps derived* from the slowness of motion in the water. Some of the side streams of the Fell Sandstone hills hurry down in floodtime especially large angular blocks, *e.g.*, on the north-west side of White Kielder. Nearly all of them have a more rapid fall than the main valley, and so a delta-shaped deposit accumulates at the foot. Not uncommonly islands of Boulder Clay occur surrounded in such deltas, *e.g.*, on the east side of Deadwater Burn about 200 yds. north of Bell's Burn foot.

Old burn-courses are rather common. Some changes seem to have been effected quite recently by drainage operations. Others, older and apparently natural, occur two-thirds of a mile west of Bewshaugh, 130 yds. north of the Ordnance Station 712 half a mile east of Bewshaugh, on the west side of Archer Cleugh rather over half a mile below the head, and 200 yds. above the bridge at the foot of Lewis Burn on the north side of the burn. In the last instance the bed of the old channel runs for a little distance through bare freestone.

The angle of slope of the present burns and the adjacent terraces is not always the same, *e.g.*, about a quarter of a mile below Willow Bog, on the north side of the burn, the terrace falls less quickly than the burn.

Of the older gravels which still retain terrace form and are clearly fluviatile we may mention the highest one on the south side of the burn near the bridge at the foot of Lewis Burn, and those near the Low Long House in the corner between Lewis Burn and the burn on the east. The gravels that form the island like hill south of Plashetts Station, and those of the narrow interrupted fringes along the Tyne between Wellhaugh Moor and the Law, are all somewhat uncertain in character. Still here and there we find indications of terrace shape, and perhaps as strong as one should expect considering the denudation that may have taken place since their formation. Their base lines seem to run at a fairly constant height above the river, a height too which is not greater than that of the well marked terrace at the foot of Lewis Burn.

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* Or we have the alternative of deriving it from the sulphur well that occurs a few yards on the Scottish side of the Border.

Peat.—This forms a general covering over all the flatter parts of the fells, but it has not been mapped where the general thickness is under 12 or 14 inches. Sometimes it even covers the face of steep scars but not uniformly or thickly. In some cases it occupies well defined hollows or basins, perhaps in part of glacial origin: in these cases the moss is shown by colour on the solid geology one inch maps. But more usually the edges are very ill defined, the peat either thinning away gradually or fringing off in long irregular arms.

Tree stems have been noticed in the peat at a height of about 1,350 ft. rather over three-quarters of a mile north of the top of Monkside, at about 1,300 ft. three-quarters of a mile east-north-east of Monkside, on Bewshaugh Moor one-third of a mile south-south-west of Black Fell top at about 1,200 ft., and many other places. The following quotation referring to the Kielder valley is copied from the Memoir of the Rev. John Hodgson, vol. i. p. 146. "Fir tree moss was set on fire about 15 years since, and laid bare the roots of a vast quantity of fir trees which had formed a thick wood, and had probably been overthrown by winds, as the trunks of innumerable large trees still remain in the moss and are often dug out for the purpose of making ladders of, and for making lows or fish lights for fishing in the night. One was found in Black Cleugh, up Kielder, and made into a table now at Kielder Castle. It contained about 20 ft. of wood besides much that came down the river . . . . . the bark underneath 3 inches thick, about 2½ ft. in diameter."

That the whole country was once extensively covered with wood is also shown by tradition. It is stated that, even within the memory of the last generation, as you came up the head of Kielder to cross over into Redesdale you could scarcely see your route for wood, a statement confirmed by the name "Woody Crags," still retained for some scars on the east side of White Kielder. The height of the crags is between 1,250 and 1,500 ft. The destruction of the woods is attributed to the sheep by many of the shepherds, and it is considered that the small patches of natural wood which still remain will also be gradually destroyed unless fenced in.

A quarter of a mile west-south-west of the Ordnance Station 1,555 on Caplestone Fell there appears to be the site of an old moss "burst." It averages some 90 yds. in breadth, and is traceable for nearly 300 yds. in a north-west direction.

Landslips.—These are very numerous, and are sometimes of gigantic size. The east side of the White Kielder for a distance of nearly a mile north of the Woody Crags is covered by slipped hummocks, &c., and the sides of Deadwater Moor are in little better case. In many of the larger slips we can see that the dip of the beds near is more or less down hill, and that this has doubtless been the originating cause. This is so both in the slips already mentioned, and in those on the east side of the Scalp Burn, 1 mile south-south-west and half a mile south-west of the

Trouting, on the south side of Rigend Burn, and three-quarters of a mile south-west of Bewshaugh. Not unfrequently the slipped material is arranged in the form of rude terraces from side to side of the slip; this is especially marked in the lower part of the great slip on the north side of Deadwater Moor.

The banks of all the burns that flow through Boulder Clay show numerous small slips. In some cases the slipped material falls on to beds of more recent age and may thus give an erroneous idea of the succession, *e.g.*, there is gravel seen close on the west side of Lewis Burn about a quarter of a mile within the south edge of the map which is overlain by Boulder Clay, but the clay is really all in a slipped condition and the gravel is not Glacial but part of a little river terrace that has been covered by the slip.

CHAPTER IX. GEOLOGICAL STRUCTURE.

The oldest beds within the Map occur in the north corner of the district within the Redesdale watershed. Here we have no doubt a small area—probably scarcely 3 acres—of Silurian rocks, but unfortunately entirely covered by drift. In the bed of a small sike about 18 yds. east of the south end of the area Silurian shales are seen in a vertical position with an east and west strike. At the south end of the west corner of the area there is a slight feature facing north-east which we suppose due to the oncoming of the unconformable Lower Freestones.

The Lower Freestones also only occur in the north corner of the map, again entirely within Redesdale. Coming south from them we cross two large faults, one east and west and the other west-south-west, each with a large downthrow south, and it is owing to these faults that we never meet with the Lower Freestones again. The faults unite just before reaching the east margin of the map.

For some distance south of these faults all the higher grounds are formed of Fell Sandstones and the valleys of Cementstones, until we get to the west-south-west fault crossing Ewe Hill and Ravenshill Moor. This is a very large fault with downthrow to south, and is most effective in altering the character of the ground in the south part of the sheet. With the exception of the area at the foot of Rigend Burn and between here and Bewshaugh we get no exposures of true Cementstones that we can be quite certain of in the south part. I think though there is a small patch between the north and south faults on Bewshaugh Moor, and on the hill where the limestone is mapped half a mile north-west of the Dinmont Lairs. Running more or less parallel to this great fault there is another one, or two near Wainhope, running by Dry Burn, Bewshaugh, and Oakenshaw Burn and again throwing down to the south.

The Geological Horizon of the Lewisburn Beds.—The position of the shaley carbonaceous beds, so strongly developed in the south part of the Map, have sometimes been misunderstood, and as the question is one of some importance we shall state in detail the evidence which shows them to come above the mass of the sandstones of Peel Fell, &c.

1. In Buck Burn—the burn descending from Buck Lakes—above the road we have, coming on above thick freestones with red clays, a series of about equally divided shales and sandstones with occasional thin coals. The general resemblance of this upper series with some of the beds in Lewis Burn is quite evident, and there is one peculiar band of calcareous marl nodules full of fossils, at a point about 50 yds. above the road, which most

closely resembles a similar band found in Lewis Burn at a point about a quarter of a mile above Low Long House. The exposure in Lewis Burn must certainly be one of the lowest beds of the Carbonaceous Series in the burn. The resemblance of the freestones and red clays with those on Larriston Fell is no less evident, and it seems too from the geological structure of the neighbourhood that they must be very near the horizon of the sandstones along the Border north and west of the Buck Lakes, even if they are not in fact the same, for all along the Border near here, and for some distance within the English side of it, these sandstones are seen dipping at angles of from 9° to 27° in a south or south-east direction.

2. In Rigend Burn one mile east of Ewe Hill a somewhat similar set of shaley beds with thin coals and limestones are seen coming on over thick sandstones. These sandstones are associated with red and purple clays of the same kind as those on Larriston and Peel Fell, and clearly overlie the Cementstone Series of Kielder.

3. In Oakenshaw Burn about one mile and a quarter above the Forks there are strong freestones with interbedded variegated red clays, and a steep east dip which would naturally take them below the Lewisburn beds.

4. The east side of Liddesdale, within Sheet 11, Scotland, from the Larriston Fell southwards, is generally not quite so overwhelmed with Drift as the adjacent English side of the Border. I believe that here there is satisfactory evidence that the carbonaceous beds of Tweeden Head, &c. come at all events above the main mass of the freestones and red clays. I cannot say though that all the freestones in Larriston Fell come below the beds at Tweeden Head; some of the higher ones may come above. The freestones below are seen particularly well in Harden Burn.

Though we thus conclude that the Lewisburn Beds come above the mass of the sandstones on Peel Fell, &c., it does not follow from this that all the carbonaceous beds overlie all the sandstones with red clays. Very likely the passage between the two types is somewhat gradual and indefinite, and could not well be expressed by a single line. The beds within this Map too are often so variable that even if there were a sharp distinction between the groups in one locality there need not necessarily be so in another; in some parts new carbonaceous beds might get intercalated between the more homogeneous sandstones of another part, or fresh sandstones and red clays might be developed which were not present elsewhere. At a point about a quarter of a mile south-west of the "C" of "Caplestone Fell" there is one inch of chocolate-coloured clay seen underlying sandstone, but the other shaley beds near are, as far as seen, greenish and sandy for the most part, and I think that the series here, and generally on the top of Caplestone Fell, may be near the passage between the two types.

The igneous rocks are confined to the basaltic dykes, the courses of which are described in detail in connexion with their

lithological character, and the Carter Fell Ash (Tuff) and Basalt. The latter rock makes a prominent green feature on the east and south-east sides of the north end of Carter Fell, and, after being thrown down south by a large east and west fault, is traceable again on the north side of Bateinghope Burn until it meets with another large fault, again throwing it down south below the ground. Owing to the number of slips and tumbled blocks which strew the fellside below the basalt outcrop it cannot be stated definitely how far either south or east the ash outcrop continues. It may be much larger than shown in the Map. In the bed of a small sike about 250 yds. below the basalt, and within 50 yds. of the Border there is a small section which shows at the base freestone, and at the top a deposit which may be either decomposing ash or merely a surface wash.

We have now briefly alluded to a few of the more important points in the geological structure of the area. In working out the details there is often considerable difficulty. This arises first from the inconstancy of the characters of the individual Carboniferous beds, which prevents the identification of distant sections with any confidence, and secondly from the great spreads of Boulder Clay which in many places completely hide the solid rocks. There can be no doubt that dislocations are very numerous, more so even than shown on the Map, and if the possibility of them were not constantly borne in mind we should acquire a greatly exaggerated idea of the variability of the beds, variable indeed as they undoubtedly are.

Faults.—Our best course now will be to give the evidence for the chief faults, including those already mentioned. Most of them are not seen in section, and we shall often have to describe the structure of the parts adjacent in order to give a proper understanding of the grounds from which we infer their presence. We shall begin at the north end of the Map and proceed south.

The Bateinghope Burn East and West Fault.—The situation of this, both in Bateinghope Burn and the cleugh on the north side of it, is fixed within a few yards by the occurrence of beds belonging to the Cementstone Series on the south against the Lower Freestones on the north. Just where it crosses the road it cuts off a massive sandstone on the south side. From this point west it is not so well defined, but it must change its course somewhat and proceed north-west; for in the sike north-west of here there are various exposures of the purple and variegated marls which belong to the Fell Sandstone Series, and therefore must be on the low side of the fault. The basalt feature on the north side is not very clear for some little distance off the fault, and therefore does not help one much to fix the position. A comparison of the basalt on either side of the fault makes the downthrow to the south perhaps about 400 ft.; it is not certain that the horizons of the basalt on either side are exactly the same but there certainly is not much difference.

The Bateinghope West-south-west Fault.—This is most satisfactorily recognisable near the head of Bateinghope Burn by the cutting off, on the north side, of the basalt and the limestone which has been worked at the low level, and on the south side, of two or three freestone scars and the Carter Fell coal. After joining the Bateinghope east and west fault it is marked, on the south side, by a strong freestone bank facing north-west; this freestone belongs to the lower portion of the Fell Sandstones Group, and it has against it on the north beds of the Cementstones and Lower Freestones. The amount of downthrow to the south, near the head of the burn, is capable of estimation by a comparison of the heights of the Carter Fell coal on either side; this makes the amount some 250 ft.

Between the head of Bateinghope and the Trouting is mainly a wilderness of peat, but the fault has been carried on through this to join one in the burn west of the Trouting, which has apparently much the same direction and also a large downthrow south, there being a small inlier of typical cementstones, &c. on the north against Fell Sandstones on the south.

The Carry Burn North and South Fault.—There is a good direction obtainable for this fault where it crosses the burn, but the hade cannot be made out. It is generally supposed that the coal 80 yds. below where the fault crosses the burn is the one seen 200 yds. or more above, and again, but much more obscurely, immediately on the east side of it on the north bank of the burn, where it is brought in by the high north-west dip close to the break. If this be so the actual break must have a downthrow to the east, though the disturbance accompanying it soon effects a more than counter-balancing change of level in the beds. The identification seems likely, because when the coal comes out of the burn again, near the old coal workings about half a mile below the fault, it is overlain by a good blue limestone, with corals and crinoids, which may well be the same as that next above the coal near the head of the burn.

The Grun North-east Fault.—Proceeding along the track that leads north from Kielder Head the first rocks come to are a series of impure yellow limestones, indicated by occasional swallow-holes, and false-bedded blocky sandstones above them. These are dipping slightly west of north at an angle of about 21°. As far as we can see from the track there is no reason to suspect a fault here, but if the sandstone scars are traced west we find a discordance in their outcrops; those to the south of the line taken as a fault running almost straight down towards the Scalp Burn, while those to the north flatten considerably and are carried some distance up the sike to the north-west, far away from their former neighbours. If we examine below these sandstones in this sike too we find that, instead of getting a series of strong sandstones like those which outcropped below them on the track, we have sandy green shales, calcareous sandstones, and impure limestones.

Evidence of a somewhat similar character is also observable on the south-west side of the cleugh that runs between the "r" and

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line taken as a fault having a stronger dip down stream then those on the east.

3. On the west side of Archer Cleugh the freestones are again at a lower level west of the line than they should be without a fault, or very rapid change in the section.

Deadwater Moor North-north-west Fault.—There are two very strong sandstones two-thirds of a mile east of Deadwater, at a locality called the Quirinal. These dip 12° or 8° north-west, and can be traced west going rapidly down hill until they are carried considerably below a sandstone scar, which they were on a level with, or superior to, at and east of the Quirinal. There must then be a fault between this scar and them, and we may judge it is probably one with a downthrow south-west, as the Quirinal sandstones are massive, and more like those that come above the adjacent scar than any known below it.

There are two crags about one-third of a mile south-east of the Quirinal which are each cut off abruptly on the east, and we may suppose this done by a continuation of the Quirinal fault.

In Deadwater Burn, not quite a mile above Deadwater, there is a fault seen in section with a hade to the west, and a direction pointing so nearly to the Quirinal discordance that we have supposed it connected with it.

The two most Northerly East-north-east Faults on Deadwater Moor.—As far as the landslips allow one to judge the general dip a little way up the fell on the south of Deadwater Moor appears to be north-west. We should therefore expect, as we proceed from north to south, to gradually get on to lower beds. Hence it is a surprise to find that starting in the Cementstone Group and going south-east we come across, every here and there, strong sandstone scars, and that the fell above them is evidently composed mainly of freestone. It is clear either that the Cementstone Group is changing its character, or that the sandstones are Fell Sandstones faulted down. At first one might favour the former alternative; for the change in the character of the hill seems in some respects a gradual one; for instance the first strong scar met may have no other strong one below it, and we may have to go some distance further south-east before we find another, and this in turn may have little but cementstones and shales below. Examination shows however that most of the appearances can best be accounted for by a series of parallel faults, all of which throw down to the south. The most southerly of these is mentioned under a separate heading as "The Ewe Hill and Ravenshill Moor Fault." Of this there is no doubt whatever. The middle one is also indicated clearly on the north side of a huge landslip. This side of the slip near its head is composed of a smoothed face of massive sandstone with a hade to the south, and conspicuously grooved with slickens. The direction of the face coincides with that of the side of the slip—about east-north-east. The northern fault is less clearly indicated, but as one stands near the top of the plantation half a mile south-south-east of Deadwater and looks up the hill along the line taken as a fault there seems a sudden

change in the character of the ground, that on the south side being more hanky, with the chief slopes facing north, and evidently formed of harder rocks.

The Ewe Hill and Ravenshill Moor Fault.—There is a great difference between the sections in the White Kielder Burn and in Rigend Burn. The former, almost up to its head, keeps in beds of the Cementstone Group, the latter for by far the most part runs through thick sandstones. Even without examining the burn-sections we see at once that there is a great difference in the beds in the two localities, from an inspection of the adjacent fellsides. The White Kielder well deserves its name from the smooth benty, or "white" ground, as it is locally termed, which slopes down either side whether drift-covered or not. The south side of Rigend Burn is in striking contrast, rough heatherclad slopes and brown freestone scars appearing one after the other as far as the eye can reach; and even on the more drift-covered north side rough freestones here and there project through in spite of the Drift.

A contrast of much the same character is to be observed between the two sides of the lower part of Archer Cleugh. The north-east side here corresponds to the White Kielder, and the south-west to Rigend Burn. The freestones of Ravenshill Moor, as they project out and narrow the Kielder valley to a gorge, are evidently in place of some much softer beds along the slope on the east of Archer Cleugh.

There are no dips observable in either of these cases of contrast which would bring the Fell Sandstones naturally on to the rough freestone hillsides, and on examining the area narrowly it is seen that the change in the characters of the ground takes place along a rude straight line, that drawn as a fault, and that there is no reason to suspect a change until we get to the line. We know also that there is a large fault with a downthrow in the required direction crossing Redewater, and that it would if prolonged with its general point join on to the line of change in this sheet. Besides this there is in the sike on the north side of Rigend Burn next to the east margin of the Map, at a point about 275 yds. above its foot, a clayey crush seen, about 2 ft. wide, with discordant dips on either side and pointing along the fault as drawn.

We might perhaps estimate the amount of throw as about 500 ft. This estimate is made by a comparison of the height of the Fell Sandstones base one mile south-south-east of Mid Fell with that of the same line half a mile or so above the foot of Rigend Burn. But as we cannot say that the beds taken as the base are the same in the two cases the estimate is only a rough one.

The hollow in which the Kielder Burn road runs half a mile west of Rigend is, though covered by Drift, very likely caused by the fault, the hard sandstones thrown down to the south forming the foundation of the knowe on this side. Proceeding from Archer Cleugh west over Ravenshill Moor the fault is traceable by the cutting off of the sandstone features on either

side every here and there. West of the north and south sike on Ravenshill Moor the line is more uncertain: there is a break in the features about half a mile south-west of the head of the sike, and one branch of the fault has been carried through this and thence on the north side of Bell's Burn foot, so as to make the strong sandstones of Bell's Linn, &c. part of the Fell Sandstones. Another branch—probably the most important—has been carried from the sike on Ravenshill Moor in a S.W. direction, to account for the sudden ending, on the south-east side of it, of the chocolate and red clays which occur one-third of a mile or so south and south-south-east of Bell's Burn foot. Going still further south-west this fault causes a conspicuous discordance of strike in the crags on the east side of Bell's Burn—the crags on the north-west side of the fault being nearly horizontal while those on the south-east are dipping steeply north-east. There is also a discordance of dip in the burn at the point where the fault is supposed to cross.

The West-south-west Fault ¼ mile South of Rigend.—South-west of Rigend this fault has been used for a short distance as a boundary of the Fell Sandstones, as if the downthrow were to the N. This may be so, because the limestone in the burnside S.E. of Riggend has a very massive sandstone over it, which might well be taken as the base of the Fell Sandstones for any evidence of upper limestones there is, but on the other hand this apparent absence of upper limestones may partly be due to their being cut off by the Grey's Pike N.N.E. fault.

Near the E. margin of the Map the fault is first distinctly recognisable by the cutting off of two sandstone scars one on either side. Each of these scars has coal close under it, and it is possible, though very uncertain, that they are the same. Should they be the same the downthrow must be N., the direction which, as stated already, is perhaps indicated S.W. of Rigend. Due N. of Monkside a scar on the S. side of the fault is cut off; about ⅛ ml. further W. another one on the N. side is treated similarly. This last scar shows a strong dip north, which is also the general dip on the north side of the fault all the way from this point to the east margin of the map. One-third of a mile or so south-west of Rigend the limestone that is seen in the burnside and the strong sandstone east of it are both in turn cut off by the fault, and 300 yds. west of the old camp a limestone outcrop with a dip of 55° to west is also cut off. The slack between this camp and the hillslope south-east probably marks the further course of the fault.

Three-quarters of a mile or so east of Rigend the fault is probably joined by another west-south-west one coming in from the west. This second fault is indicated in a sandstone scar due south of the "R" of "Rigend Burn" by a steep sudden dip at right angles to its course, and again in Rigend Burn itself by the loss of the limestone before it comes into the burn.

North-east Fault half a mile East of Monkside.—Three-quarters of a mile south-south-east of the Three Pikes there is a strong

sandstone crag which on its north side is cut off and its face slickened. A good point for the fault is obtainable, and a search along the line indicated shows further evidence of it. In a S.W. direction 200 yds. or so beyond the north and south burn on Wainhope Moor a sandstone scar is cut off on the north side. In a north-east direction three sandstone crops are cut off in succession, within a distance of one-third of a mile of the scar, and three-quarters of a mile further on another sandstone scar is cut off.

No evidence as to the throw was found, except at the crag three-quarters of a mile south-south-east of the Three Pikes. Here the slickened face shows a hade to the west, and it is just suggested that the crag 50 yds. west may be a repetition of it on the downthrow side. If this be so the amount of throw must be 50 or 60 ft.; if it be not so the throw must be larger, but how much larger cannot be said.

The Grey's Pike North-north-east Fault.—For nearly the whole of its course this fault shows discordant dips on either side. Starting at the north end we notice them first on tracing uphill the limestone that occurs in the burnside one quarter of a mile south-south-west of Riggend, and the strong sandstone scar 50 or 60 yds. further east. The limestone has but a gentle rise to the south, while the sandstone runs up suddenly and is soon carried a long way from the limestone. At the head of the sike half a mile west-south-west of the Three Pikes the beds west of the fault are dipping east at 45° or more, while on the east the dip is only gentle, and on the fell a little north the outcrops of the beds are level. Between the head of this sike and some distance south of Grey's Pike we have on the west side bed after bed of sandstone, in an ascending series as we go south-west, striking against the fault, while on the east we keep along the outcrop of but one or two beds.

The sharp easterly dip rather over one third of a mile south-south-west of Grey's Pike is probably connected with this fault. On the north side of Gowanburn Moor it has been drawn as consisting of two branches. The east branch is marked by a sudden dip of 58° in a sandstone scar on the east side of it, and from thence south-west a succession of sandstone scars are cut off on the same side. The evidence for the west branch consists in the cutting off of these sandstones on the east side of it, below the head of the burn, and the cessation of the swallow holes on the west side.

The downthrow is east and probably of large amount. This is indicated both west of the Three Pikes and on Gowanburn Moor by the occurrence on its west side of shales, limestones, &c., which belong to the Cementstone Series, while on the east are Fell Sandstones.

The North-north-east Fault half a mile East of Three Pikes.—The great depression in the fells half a mile east of Three Pikes is at once suggestive of a line of fault. On examining the ground near, we find that as we ascend the steep south side of the Three Pikes we pass over a succession of sandstone dip-slopes, and that

the higher we get on the hill the lower we get in the beds. Keeping on the east side of the upper part of the north and south burn on Wainhope Moor we find however no such steep dip, but merely one that appears to suffice to keep the same bed at or near the surface of the gentle slope, so that this bed seems at one place to be on a level with a sandstone on the south side of the Three Pikes that in another place it must be many feet below. Between these areas there is a little breadth of obscure peaty ground, through which the fault is supposed to run. One cannot say in what direction the throw is.

East and West Fault half a mile South-east of Three Pikes.—The lower coal that has been exposed by the drainers 50 yds. north of the fault is very hard and comes up in good sized blocks—in fact it is peculiarly deserving of the local term "splint." About 25 yds. south of the fault and 12 yds. east of the stream are indications of a very similar coal, in all probability the same. This makes the downthrow south and perhaps 30 ft. or so in amount.

The Dry Burn Head North-north-east Fault.—The coal exposed by the side of the east drain at the head of the burn is, including a 7-in. parting of fireclay, almost exactly 3 ft. thick. 120 yds. or so north-north-east of this point a shaft was sunk about 20 years ago, and a coal, also about 3 ft. thick, is said to have been found at a depth of 2 or 3 yds. It was suggested that these coals so nearly alike might be the same, and on further examination additional reasons for this supposition were obtained. In the first place it was noted that a crag to the north-north-east (the Long Crag) is suddenly ended at the prolongation of a line that would pass between, and close to, the two known coal localities; in the second place, that further down the fell to the south-west there were again two occurrences of coal near to one another, each about 10 in. thick, and that the line of fault already suggested would pass naturally between them.

The amount of downthrow to west probably need no exceed 20 ft.

The Wainhope Moor East and West Fault.—In Dry Burn, about one mile above Wainhope, a good grey crinoidal limestone is seen dipping up stream. Its thickness is not clear, because it is a good deal decomposed into ochre, but perhaps an estimate of 4 ft. might be ventured on. A limestone of much the same character, and again prone to decomposition, occurs in the east head of the sike that runs between Dry Burn and the North and South Burn on Wainhope Moor (Wainhope Burn), and also in this north and south burn itself. The dip in all three places is generally more or less north, and at rather high angles. It is hence suggested that the strike between the places is rudely east and west, and that the limestones so similar in character are in fact identical. Now in the Dry Burn exposure the limestone is almost on a level with a sandstone 120 yds. north-west, which, as it runs north-west, gets to be 200 or 300 ft. above the Wainhope Burn exposure; so that it seems necessary to suppose a fault between the sandstone and

the limestone. With this agrees the fact too that the sandstone mentioned and also the one next above it are both sharply ended at their extremities nearest to the Dry Burn limestone.

A little below the limestone in Dry Burn is the supposed Plashetts seam, which has been opened out in a short level near the "n" of "Dry Burn." This coal is said to be about 4 ft. thick, and to have a thin shale-parting, much like that usual in the Plashetts seam. Such a coal is not seen either in Wainhope Burn or the intermediate sike, but there is no evidence that it does not exist, and if the argument for the identity of the limestones be good then we should expect also to find the coal in these places on trials being made.

Some persons may find additional evidence for the fault from their identification of the Yard coal half a mile south of Monkside (and of Hunter's Burn Head, in 108 S.E.) with that of the Dry Burn level; supposing a fault with large downthrow south to pass between this level and the other localities mentioned. But we are not satisfied that the identification can be relied on.

The Bewshaugh Moor North and South Faults.—The most easterly one of these makes itself evident in Catcleugh Burn by the sudden appearance, on the west side, of a steeply dipping limestone band, while on the east have been for some distance comparatively gentle dipping sandstones, calcareous or not, and grey shale. There are also slickened freestone blocks, evidently nearly in place, just where the break should pass. On the south side of the burn the fault can be satisfactorily traced a quarter of a mile or more by the shattered condition of the sandstone on the east face of some crags called Cat Cairn crags. The throw is probably down east, for the beds in the burn west of the fault have a much more Cementstone aspect than those on the east. Between the faults the beds are much contorted and disturbed.

The west fault crosses the burn 75 yds. above the east one, and can be traced south going between the Cat Cairn crags. There is a gulley on either side of the burn where it passes, which has no doubt been caused by it. A limestone band on the east is cut off, and we get instead strong sandstones. Close to the gulley a disturbance starts off in a south-west direction; this may be continuous with a crush in the shattered sandstone in the south head of Catcleugh Burn.

The Dry Burn East-north-east Fault and the East and West Fault South thereof.—The freestone band 120 yds. slightly west of south of the old coal level near the "n" of "Dry Burn" is underlain, in a south-westerly direction, by at least 3 or 4 bands of massive pillowy-weathering freestones forming the "Millstone Crags," &c. There is clearly little, if any, shale coming between them, and no sign of coal or limestone. What then is the relation of these sandstones to the coal of the old level and the overlying limestone and shale? The coal in the level is said to dip very steeply south-south-east, so that it could not get above them without a fault. Equally impossible does it appear for it to get

below them. Hence a fault has been drawn between the coal and the massive freestones.

The East and West Fault South of Wainhope is clearly recognizable most of the way between Wainhope and Belling Burn. It cuts off scar after scar of the Millstone Crags, and also various sandstones east of the sike marked between Dry Burn and Belling Burn, and one just east of Belling Burn. East of Wainhope we have joined it up doubtfully with an apparent discordance in the burn about a quarter of a mile below Wainhope. One of the Millstone Crags shows, close to the fault and doubtless under its influence, a sharp change of dip to the south, and there is a similar change in the crag next east of the sike between Dry Burn and Belling Burn.

If we suppose the coal of the Dry Burn level to be the Plashetts coal, as is usually believed and seems probable, then a little inspection of the ground makes it evident that it must be thrown down south many hundred feet before we next know it on Plashetts Moor. The Piper's Cross limestone, half a mile or so east-south-east of Wainhope, occurs 100 ft. below the Dry Burn level, and the limestone in the vertical section is perhaps about 460 ft. above the Plashetts coal, so that the downthrow would seem to be about 600 ft. But between the two exposures we have both the faults just described, and the share to be attributed to each is somewhat uncertain. In all probability they both throw down in the same direction, south, because the Millstone Crags are unlike anything known in the neighbourhood for some distance below the Plashetts seam, but are not unlike some of the strong sandstones a little way above it, on the brow above the outcrop on Plashetts Moor. There is also a fairly good blue limestone seen in the east head of the Belling Burn, one mile east of the "y" of "Dry Burn," which contains corals and crinoids, and may possibly be the Piper's Cross limestone, though here there is sandstone immediately overlying it instead of shale.

We have supposed the two faults to unite under Drift about half a mile east of Wainhope, and then to proceed, still almost entirely under Drift, until we get a little north-west of Dinmont Lairs. There is here a break in the hill-outline which is at once suggestive of a fault, and on examination we see a discordance of dip along it, the swallow-hole forming bed on the north-west side striking against a massive freestone on the south-east. We suppose the former bed to be either just above or just below the line we have taken in the north part of the Map as the base of the Fell Sandstones, and the freestone to be some distance up in this series, but the ground is too obscure to say how far.

In the burn close by Oakenshawburn there are two fault-breccias which are running much in the direction necessary to join the one we are attempting to trace. The most northerly one is probably the chief branch: this is seen again crossing the burn 300 yds. above the house and again rather over half a mile above. From this place west it passes for rather over half a mile through a thick Boulder Clay area. Then we come to a great bank-feature facing

north and running in a direction about west-south-west, the beds on either side of which seem discordant wherever they are seen, *e.g.*, in the sike that comes into Needs Burn from the south between the "s" and "B" of Needs Burn. This bank continues prominent up to the Cumberland Border.

At Oakenshaw Burn there would seem still to be a considerable downthrow south, if we can, as seems probable, rightly correlate the freestones and red clays 200 or 300 yds. south-east of Oakenshawburn house with the very similar ones near the head of Little Burn, and a quarter of a mile west-north-west of Willow Bog. Further west, along the great bank-feature, the dips on either side are so high and various, and at the same time the beds are so largely obscured by Drift or peat, that we have no confidence to say anything about the throw. There are also two faults leaving it for a more southerly direction, and these may take some of the throw away.

A little west of the Cumberland Border the fault seems again to fork into two, with throws in opposite directions apparently, the west one throwing down south-east and the east one down north-west. The beds between the two faults, as seen in the small sike marked in the Map south of Lazy Knowe, and in the further course of this sike in 106 N.W., are sharply disturbed and intersected by a number of cross-faults of unknown magnitude. They consist of a group of sandstones and shales, which probably come considerably above the cherty beds at Kershope Head; the sandstones as a rule are not very thick or massive; the shales are mostly dark grey and carbonaceous. There are also some calcareous grits and one or two 6-in. coals. The disturbance of the beds may be looked on as the result of their compression between the two lines of fault.

The Lewis Burn Great North-east Fault.—This is seen very distinctly about one-third of a mile above the Forks. The beds on the south-east are suddenly tilted up into a vertical position, with the strike parallel to the direction of the fault. Following along this direction north-east we again see the fault exposed near the head of the small sike half a mile or so north-east of Lewisburn colliery; and for several hundred yards east of this sike it can be traced by the cutting off of three sandstone scars on the south-east side. Beyond this nothing is known of it for certain, but miners generally suppose it to cross the Tyne just at the foot of Lewis Burn, and there are valid reasons for this supposition; for the sandstone close to the river, east of the line as drawn, seems to occur too close to the sandstone west of it to allow the coals and shales that should come above this west sandstone to get in. We have after this continued it, under Drift mainly, to join the north-east vein in Plashetts Burn below Wainhope, but this is very doubtful.

No hade can be made out in either of the exposures seen, nor are there any beds which we can with certainty identify on both sides. Numerous attempts to do so have been made by the miners, but very few agree among themselves, and it would seem

that the beds in this neighbourhood are usually too variable to allow of identification over large areas. Some suppose the Lewisburn Kiln coal* to be the Barney's Cut coal, and also the Serpent Brae coal. Others take the Old Bridge coal on the south-east side of the fault to be the Low Level House coal on the north-west side. Both these identifications make out the downthrow to be north-west and of considerable amount, and in this they are probably right. The general resemblance of the beds in the gorge one-third of a mile above the foot of Lewisburn Bridge with those half a mile above the Forks is sufficiently striking; they have clearly been deposited under much the same conditions, and very possibly at the same time.

Supposed Fault in the Plashetts Waggon-way Gap.—It is a common opinion that the gap in the hills one mile east-south-east of Plashetts Station, through which the waggon-way proceeds to the colliery, is caused by a fault of considerable magnitude, throwing down the Plashetts seam to the south, so that it should outcrop again a little north of the Law. I have however never heard of any exposure near the latter place that is supposed to represent it, and, though the gap in question does undoubtedly suggest a fault, I could not satisfy myself, from the lie of the beds on either side, that there necessarily was one. It seems hard to see, too, where such a fault could cross Belling Burn, unless it were here running closely parallel with the Lewisburn basaltic dyke, and in this case a rather unusually sharp change of direction would be required to take it through the waggon-way gap.

Faults in Kershope Burn, the burn along the Scottish Border west of Caplestone Fell.—From a quarter of a mile above the point where the Northumberland-Cumberland Border meets this burn to about one-third of a mile below it the beds consist of sandstones, carbonaceous shales, thin bands of calcareous grit, and impure limestones and thin coaly layers. These have a general north-west dip at from 10° to 30°. Further down stream the beds suddenly become horizontal, probably on the further side of an obscure line of fault of unknown throw. A bed of calcareous grit then occupies the bed of the stream, level or gently undulating for about one-third of a mile, when it is found to form the base of a sandstone scar. Close to the south margin of the Map this scar of sandstone with its calcareous base is truncated against a very massive crag of sandstone. The fault that causes this change runs slightly west of south, and has a decided hade to the east, but its effects are not known.

The Lewis Burn East and West Fault.—A fault, running roughly east and west, is inferred with confidence in the north and south cleugh south of Low Long House, 100 yds. or so within the adjoining quarter sheet 106 N.W. It seems certain that a large fault, with a throw in the same direction as this one, crosses Lewis Burn 300 yds. or so above the Witch Linn. The beds

* For the names and positions in section of the various seams mentioned here see pp. 56, 57.

here and for some distance on the north are very much confused in arrangement, and belong to the lower part of what we call elsewhere the Lewisburn Series. They contain many coal seams, impure limestones, &c. On the south side, on the contrary, the beds are lying much more evenly, and consist chiefly of massive soft freestones, which we suppose to represent the Fell Sandstones of the Peel Fell escarpment, &c., and in the natural section to underlie the carbonaceous beds on the north side of the fault. We suppose the throw then to be down north, and at least several hundred feet in amount.

Close to where the fault is supposed to cross the burn crushed rock is seen, but it shows no satisfactory indication of the direction of the crushes. Immediately on the south side there is a thin basaltic dyke running parallel, and still a little further south is a very deep hole* in the burn with massive sandstone on the sides. Can the hole be connected in any way with the crushed fault-rock?

On the west of the burn there is an obscure fellside deeply covered by Boulder Clay and peat, and it is not possible to trace the course of the fault through it with exactness.

The faults marked half a mile or so below Lewisburn Forks, west of Wellhaugh Moor, near the head of Mounces Burn, and those in the Plashetts workings are all put in from miners' information, and we here cordially acknowledge the kindness and ready help we have received in all cases from those to whom we applied.

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* This is said to be 22 fathoms deep! It is locally known as "Hell's Bottom."

CHAPTER X. SOME ASPECTS OF SCENERY IN RELATION TO GEOLOGY.

Where bare of Drift the Fell Sandstones of Peel Fell, Carter Fell, and all the northern heights, consisting as they do for the most part of massive blocky freestones, form rough heatherclad fells with scar after scar, and contrast strongly with the smooth benty green or "white"* slopes of the underlying Cementstone Series. The contrast is seen particularly well in the Peel Fell escarpment, and on either side of the White Kielder. Perhaps the wildest and most rugged bit of scenery within the Map occurs near the head of the Scalp Burn, where the scars of sandstone are especially massive.

The individual limestones of the Cementstone Series do not, as a rule, make the prominent fresh green bands that the limestones in some districts do. This is probably owing partly to their want of purity and partly, to their thinness, which allows the outcrops to be readily obscured by any movement of the soil-cap or by Drift.

The Carter Fell basalt makes a green feature near the top of the fell, which is very prominent in the distance as you cross the Border by the Redewater road.† The basaltic dykes, where their outcrops are free from Drift, usually form green rather ridgy ground, or else slacks when running across sandstone scars.

In tracing out the faults of the district one cannot help noticing how very frequently they cause conspicuous breaks in the hill-outline, gaps, slacks, &c. These effects are necessarily alluded to in describing the courses of the individual faults, and we may here only mention, as conspicuous instances, the slack south-east of the camp three-quarters of a mile south-west of Rigend, and the great feature facing north-north-west on the north-west side of Caplestone Fell. The effects produced must be supposed to be due partly to the throwing together of beds of different hardness, and also, in the case of slacks with beds of much the same hardness on either side, to the actual crushing of the rock in the fault or close by its side, so that a line of weakness has been formed, along which denudation has acted more rapidly than elsewhere.

In the west and south portions of the Map the great spreads of nearly homogeneous Boulder Clay cause the hills throughout to be comparatively featureless, springless, and monotonous. Still features of a kind are not wanting even in this Boulder Clay, as described pp. 26, 29. Their general direction is south-east. Though individually not to compare with rock features for definiteness or

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* Local term for the kind of ground described.

† The old coach road from Hexham to Edinburgh.

continuity, yet when taken together they are enough to give decided character to the landscape.

The wide desolate tops in the north part of the Map are covered with an all but universal covering of peat, which is now in many places getting gradually wasted away into dreary black "hags."

CHAPTER XI. ECONOMIC RESOURCES.

The cultivated ground is of very small extent and chiefly confined to the river sides. It appears that there was once rather a larger area: this is shown by tradition and also by the old plough-furrows on what is now moorland, *e.g.*, between Belling Burn foot and the Law. There are also the ruins of an old corn mill and malt kiln up Belling Burn about one-third of a mile above the foot. The Plashetts Colliery no doubt affords, when times are good, work for more persons than the old plough-lands did; but the other smaller collieries and also various limekilns are now abandoned. There is an interesting relic of these old pre-railway times at the "Bloody Bush," where the Oakenshaw Burn road crosses the Border, consisting of an engraved table of tolls for cattle, coal carts, &c., built into a stone column. This road was once, as testified by the solidity of the bridges, the chief means of communication between North Tyne and Liddesdale, but now it is scarcely ever used except by the Newcastleton carrier once a fortnight. The old drove roads, too, particularly prominent between Wainhope and Bellingburn Head, on Gowanburn Moor, and half a mile south-west of the Three Pikes, are now seldom used, and their deep ruts are getting gradually more obscure.

Before the Belling Burn level was started the Plashetts seam was extensively worked for the Duke of Northumberland's tenants near its outcrop on Plashetts Moor. The pit that was last working is close on the south side of the track between Plashetts and Bellingburn Head. In 1870 the produce power of the present colliery was reported to be about 400 tons per day, the actual vend being 170 tons; but in 1882 work was being carried on on a decidedly smaller scale. The "round coal"* brought out of the seam is considered a fair house and gas coal, but the gas requires rather extra purifying owing to the quantity of pyrites contained in the coal. Coke is made out of the "small" at the ovens close to Plashetts Station; the greatest proportion of it is at present (1882) used in the Liddesdale limekilns. The "brasses" (nodules of iron-pyrites) in the coal are collected and sent by rail to Kirkcaldy. The fireclay below the seam has been worked at the colliery for burning into bricks, and, when mixed with a certain proportion of shale from the roof, for tiles. The thickness of the clay varies from 1 to 3 ft. The colliery workings are practically all on the east side of Belling Burn, and to a large extent within the Map to the east (108 S.E.). It is proposed now to begin working the seam on the west side of the burn from a level starting about half-a-mile east-north-east of Plashetts Station. For the possible continuation of the seam elsewhere see pp. 9, 10, 46, 47.

* Big lumps of coal.

The thicker and better seams in Lewis Burn have been worked in many small old levels, &c., but no work is done in any of them now, excepting occasionally in a very small way by the shepherds to eke out their supply of peat. The steep and suddenly varying dips, and the numerous faults of the district, must cause more than usual difficulty in following the seams, draining the workings, &c. The Old Bridge coal, (see p. 57), though only 13 in. thick, has the reputation of being perhaps the best of any of the seams as far as quality goes.

The Carter Fell coal was largely worked, especially on the English side of the Border, about 40 years ago. Very much of it was carted away to Jedburgh for house coal: it is said that as many as 90 carts were sometimes there in the morning waiting to be filled. The esteem in which it, together with the upper Carter lime, was once held, may be estimated by the length of good road, made expressly to them, across the desolate fell from the Redesdale coach road.

The thin courses and rows of clay-ironstone nodules* in the Lewis Burn shales were, within a comparatively recent date, collected and sent away for smelting. In earlier times they seem to have been smelted in the district itself, and heaps of slag derived from them are found here and there, *e.g.*, not quite a quarter of a mile north of the Law, near the foot of Belling Burn, and one-third of a mile north-north-west of Wind Hill. The old levels rather over one-third of a mile north-north-east of the Law may have been driven in search of them.

The limestone at the head of Bateinghope Burn at the top of the Cementstones has been worked in a level, and burnt at a kiln close to the mouth thereof. The level has long since been abandoned, and the limestone is said never to have been so good as that above the Carter coal. This upper limestone was, 40 years ago or more, extensively worked in two large quarries on the fell top three-quarters of a mile or so east-south-east of the Ordnance Station 1815, and was burnt at some kilns near where the road crosses the head of Bateinghope. The kilns and neighbourhood are now locally known as the "Concern," a name presumably given in consequence of the great stir or concern they formerly made in the district when working.

The Piper's Cross limestone is a good blue limestone and has been worked in many small old quarries for burning into lime. It has sometimes been projected to work it extensively in connexion with the Plashetts colliery.

There are various extensive quarries in the freestones on the west side of Deadwater Fell within the Fell Sandstones Group. The stone from these was formerly taken into Scotland in large quantity, but they are all now abandoned. The sandstone at present worked on the Scottish side of the Border close to Deadwater Station is not one of the Fell Sandstones, but a bed within the Cementstone Group.

* Locally called "catheads."

The deserted quarries at various places lower down the Tyne valley in the immediate neighbourhood of the railway were all started merely to help in the construction of the line.

The topmost crag—Pithouse crag—of freestone above the outcrop of the Plashett's coal about a mile north-east of Plashetts station was formerly used for making into grindstones.

None of the igneous dykes in the district have been opened out even for local use. The Carter Fell basalt has been quarried in one place for road metal to help to make the road up Bateinghope. It is a sound compact blocky rock, and looks as if it should answer well for street setts, &c., but a little preliminary working under the hill would be required in most cases before getting through the tumbled pieces which largely obscure the outcrop. It is also of course very far off any railway, or other convenient means of carriage.

Where the country is free from Drift there is generally no lack of good springs. Among those that come readiest to memory are several a little south of the "Cr" of Cross Cleugh, Bateinghope, several near the base of the Fell Sandstones at the head of White Kielder, several a little east of the head of Archer Cleugh, and various in the alluvium west and north-west of Kielder* Station. Owing to the great spreads of homogeneous Boulder Clay they are comparatively rare in the south and west portions of the Map: we may note however one very good one that comes out close by the south side of the Lewisburn Dyke about 30 yds. west of the railway cutting, and two strong ones near the head of Bells Burn, one about a quarter of a mile west of the "B" of "Bewshaugh Moor" and the other about the same distance west of the Ordnance Station 1,322. The last mentioned goes by the name of "The Duke's Well."

In the sharp bend of Lewis Burn, a little over a quarter of a mile south-west of the bridge near the foot, there is a sulphur spring coming up in the river bed out of freestone; it is not visible except the stream be low. There is another spring of much the same character on the south bank of the Tyne, about a quarter of a mile east of Otterstone Lee, which is called the "Holy Well."

* The word "Kielder" is possibly derived from the old word "keld," a spring, (Norse *kilde*) which we believe is still used in some parts of the north of England.

APPENDIX.

Sections in the Carboniferous Rocks

Section in Lewis Burn, below the Forks.

(From above.)

	Ft.	In.	
Rather massive sandstone	6	0 +?	
Coal	0	8	
Shale	12	0	22 ft.
Thin flaggy sandstone	10	0	
Splint Coal	0	8	
Shale	4	0	
Rather massive sandstone	6	0	
Yellow calcareous sandstone	1	0	31 ft.
Flaggy sandstone	6	0	
Rubbly flags and sandy shale	12	0	
Shale	2	0	
Coal	0	8	
Shale and thin shaley sandstones	22	0	
Low level fire or house coal	1	6	
Shale (chiefly)	40	0	
Coal, at times a good splint	1	0	
Shale (chiefly) with light grey shale at top	15	0	
Coal, splint	0	6	
Grey shale	0	6	
Light grey clayey shale	0	6	27 ft.
Rather massive sandstone	15	0	
Grey shale	11	0	
Coal, mostly splint	0	6	
Light grey shale	2	0	
Rubbly sandstone flags	4	0	18 ft.
Shale with some calcareous grey flags	12	0	
Coal	0	10	
Shale and fireclay	4	0	
Thick flaggy sandstone	15	0	
Shale	20	0	61 ft.
Calcareous grey flags	10	0	
Calcareous grey flags and shale	12	0	
Coal	1	0	
Shale	12	0	
Coal, splint	1	0	
Shale	6	0	
Calcareous grey flags	8	0	20 ft.
Shale	6	0	
Barney's cut coal	1	6	
Shale	14	0	
Calcareous grey flags	3	0	
Shale	2	0	
Yellow calcareous sandstone	1	6	
Shale	10	0	
Barney's cut sandstone. Top blocky post	8	0	
" " " Thinner posts with some shale	6	0 +?	

Section in Lewis Burn above the Forks, but below the N.E. Fault.
(From above.)

	Ft.	In.	
Massive sandstone	8	0	
Flaggy sandstone	12	0	
Shale	1	0?	
Coal	0	6?	
Shale	1	0?	
Sandstone post	2	0	
Shale	7	0	16 ft.
Hard yellow calcareous sandstone post	1	0	
Shale	5	0	
Coal	0	7	
Shale	5	0	
Rather massive sandstone	6	0	
Shale (chiefly)	18	0	
Massive sandstone	30	0	103 ft. 2 in.
Sandstone, massive or flaggy	20	0	
Shale and thin flags	12	0	
Coal	0	2	
Shale	12	0	
Coal	from 1 to 6		
Shale and calcareous grey flags	12	0	
Coal	0	4	24 ft. 4 in.
Shale and calcareous grey flags	12	0	
Serpent Brae coal	1	6	
Shale (chiefly)	20	0	
Yellow calcareous sandstone or impure limestone	4	0	
Shale (apparently)	6	0	
Yellow calcareous flaggy sandstone	4	0	
Massive sandstone	17	0	
Shale and impure limestone	6	0?	
Massive sandstone	20	0	

Section in Lewis Burn above the N.E. Fault.
(From above.)

	Ft.	In.
Supposed Plashetts coal said to vary from	2	8
to	4	11
Strata	40	0
Coal	1	0
Sandstone, shale, thin coals and some yellow limestone posts	320	0
Old Bridge coal	1	1
Shale, with sandstone flags and calcareous grey flags	52	0
Coal varies from	0	6
to	1	2
Shale with sandstone and calcareous grey flags	45	0
Productus limestone with shale parting	11	0
Shale with calcareous grey flags and some sandstone	160	0
Lewisburn house or fire coal	1	6
Sandstone and shale	45	0
Lewisburn kiln coal	1	6
Shale with calcareous grey flags, some sandstone and thin coals	200	0
Foot of Whiskey* Sike coal	1	0
Shale and flags	105	0

The above section is generalised to avoid the great length it would otherwise attain; but probably not much of value is omitted, for the details vary rapidly in short distances. The upper 200 feet is not very reliable being only seen in small sikes, &c.

* Up this sike there are ruins of an old illicit still.

Section on Plashetts Moor from the Plashetts Coal to the Piper's Cross Limestone.

(From above.)

	Ft.	In.
Shale with ironstone nodules	—	—
Piper's Cross Limestone	15	0?
Thin flags and shale	50	0
Apparently mostly sandstone	70	0
Piper's Cross coal	2	6
Sandstone, mostly massive, but sometimes thinner bedded, and probably some shale occasionally	260	0
The Dun Limestone horizon: ? if the bed exists here	5	0
Freestone	30	0
Shale	22	0
Limestone	2	0
Shale	6	0
Coal	1	3
Shale	12	0
Plashetts Seam	4	7
Grey shale	2	0
Coal	0	2
Shale	18	0
Coal	1	0

The 73 feet above the Plashetts seam are given as they were proved in the old Plashetts Pit below a surface covering of 12 feet of soil and clay. The rest of the section above this is chiefly by estimation and one cannot safely insert details.

Section in Belling Burn near the Plashetts Seam.

(From above.)

	Ft.	In.
False-bedded sandstone	35	0
Shale and sandstone	20	0
The Dun Limestone, with crinoids, rather dark grey internally, but weathers yellow, inclined to decompose into ochre	5	0
False-bedded sandstone with a few feet of shaley portions	40	0?
Shale probably	20	0
Impure yellow weathering sandy and rather flaggy limestone	1	6
Flaggy sandstone	2	0
Shale probably	15	0
Shelly calcareous sandstone with Entomostraca	0	8
Plashetts Seam	4	7
Mostly shale with ironstone nodules	25	0
Sandstone post	1	6
Shale	10	0
Hard sandstone post	1	2
Shale	4	0+?

Measured Section of Strata in Borehole at Cloven Crags, Plashetts.

Supplied by Mr. Jas. Aitchison the manager of Plashetts Colliery.

(From above.)

	Ft.	In.
Yellow freestone	88	8
Grey metal	15	3
Bastard whin	2	10
Red freestone	6	9
Blue metal	2	8
Red freestone	3	6
Grey metal with iron girdles	5	5

	Ft.	In.
Freestone (white and yellow)	15	0
Blue metal	21	4
Black metal and whin	1	6
Blue metal	7	3
Grey metal with post girdles	6	9
Blue metal	5	8
Coal (called Little Coal)	1	0
Blue metal	8	6
Grey post and iron girdles	0	9
Coal. Plashetts Main	4	6
	197	4

The position of the above borehole is scarcely three-quarters of a mile from Bellingburn Head, about 50 yds south of the track leading between there and Plashetts.

"Metal" is the local term for shale. Any very hard rock may be called "whin"; in the above section the word probably applies to hard compact sandstones or impure limestones.

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